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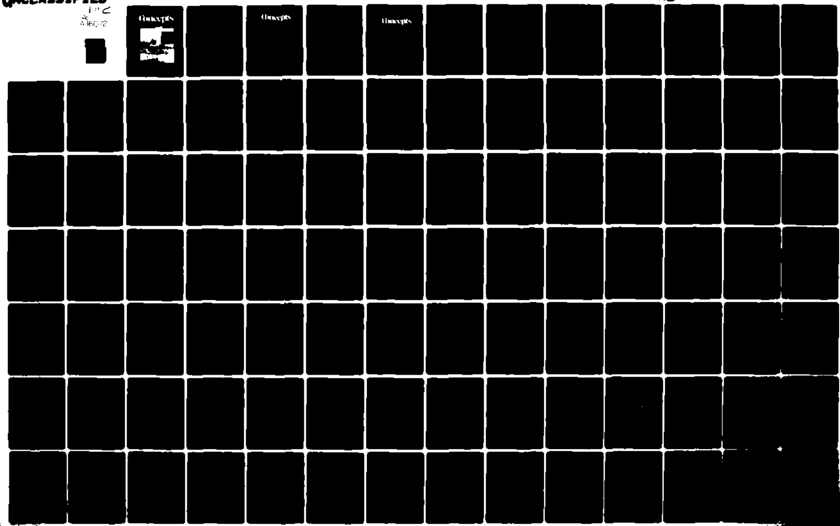

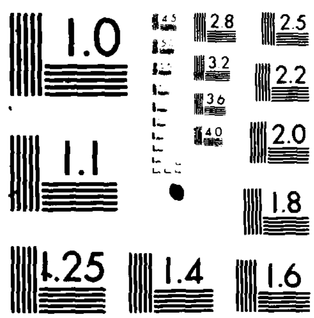

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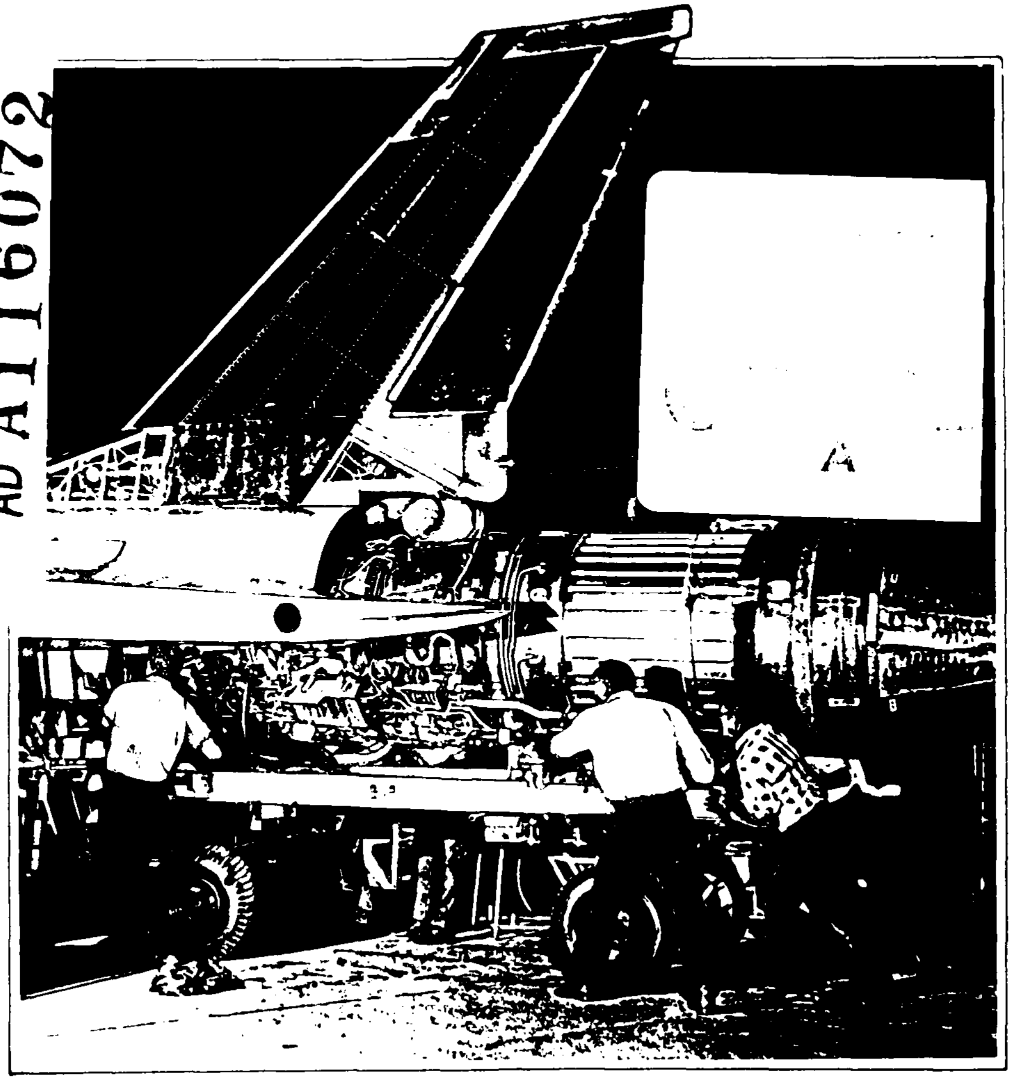

Two Perspectives on Multiyear Procurement
European Overview Part II
Competition: Does It Lower Costs?

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from the editor . . .

As we noted a couple of issues ago, the Research Directorate of the Department of Research and Information here at the College has been deeply involved for more than a year now in spreading the word about the DOD Acquisition Improvement Program. Members of the Directorate, sometimes accompanied by faculty members of DSMC's School of Acquisition Education, have logged thousands of miles in an effort to communicate the directions and implications of the improvement program to acquisition managers throughout the country.

Becoming well-versed in the many policy implications of the 32 acquisition improvement actions required a lot of leg work and countless hours of background research, followed by even more hours of revision, refinement, and updating. The results of all this is that an enormous amount of information has been gathered and synthesized regarding the 32 improvement actions and their implementation. Much of the information will be included in the summer issue of *Concepts* scheduled to be in your hands by mid-July. That issue will be devoted exclusively to the Acquisition Improvement Program. The purpose is to update you on where the actions stand as of this spring and to alert you to areas where you can now take advantage of policy changes or new directions. This will be the biggest, and possibly the most important, issue of *Concepts* ever. Don't miss it.

You were no doubt surprised, and I hope pleased, to have received a copy of the revised DOD Directive 5000.1 less than a month after the Deputy Secretary of Defense signed it. Although this was a part of the College's continuing efforts to keep the acquisition community informed about policies affecting them, it could not have happened without the extraordinary efforts of a lot of people, two of whom deserve special recognition. First is John McKeown, late of DSMC's Research Directorate, now head of the Flight Controls Section at HQ, Naval Air Systems Command, who hit upon the idea of using our publications mailing list to rapidly get the new directive into circulation, and who coordinated the effort from the DSMC end. Next is Fred Reinhard of the Office of the Under Secretary of Defense, Research and Engineering, who coordinated the effort from the Pentagon end, taking the bull by the horns, and sometimes by the tail, to have the directives printed and prepared for mailing. You got your copy of the directive only because these two men were creative, dedicated, and determined enough, and had enough bureaucratic savvy, to make this thing happen. It's great to know there are people who are willing to go out of their way to get the job done. We owe them thanks.

7 Our Management Heritage for the '80s

Richard F. Gordon

The seeds for management thought in the United States were sown when Captain John Smith of the Jamestown Colony defined the term "work ethic." His definition was simplistic, yet easily understood: "Those who don't work shall not eat." From this humble beginning the American work ethic evolved into the belief that work is not only necessary, but is valuable for its own sake. This philosophy, rooted in the harsh facts of life, remains an essential part of our national heritage.

In 1776, one of the earliest and most famous examples of task specialization was addressed by Adam Smith in his book, *The Wealth of Nations*. In effect, he put forth a management concept that demonstrated the principle of division of labor. The labor process Smith studied was the manufacture of pins. He showed that dividing labor by task enables the same group of workers to increase its daily production from 200 to 48,000 pins a day. Ironically, toward the end of his book, Smith points out one of the major shortcomings of the division of labor.

> The man whose whole life is spent in performing a few simple operations, of which the effects too are, perhaps, always the same, or very nearly the same, has no occasion to exert his understanding or to exercise his invention in finding out expedients for removing difficulties which never occur. He naturally loses, therefore, the habit of such exertion and generally becomes as stupid and ignorant as is possible for a human creature to become.

Eli Whitney further hastened the arrival of our industrial society when he invented the cotton gin in 1793; it marked the advent of mechanization. Whitney is also thought to have introduced the principle of standardization when he manufactured muskets using interchangeable parts in 1801.

With the advent of industrialization, workers were viewed as economic creatures without rights or entitlement. The classical theory of motivation simply states, "Money is the sole motivation in the work place." Frederick Taylor, the father of scientific management, was its chief exponent, and all of his work-improvement efforts were directed at the task. Taylor advocated analyzing jobs and breaking them down into simple, repeatable tasks to maximize efficiency. Adjustments between technology and human needs were made in terms of the individual's adjustment to the system, rather than designing the system to meet human needs.

In 1913, Henry Ford put it all together—Smith's division of labor, Whitney's mechanization and standardization, and Taylor's scientific management. Ford's

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new synergistic concept was the moving assembly line. Within 6 months he reduced the assembly time for a Model T chassis from 12½ hours to 1½ hours. This mechanistic approach to work helped create a horn of plenty, but it also created a monotonous, machine-like routine for millions of workers.

During the capital-formation phase of our industrial society, the laborer work force was composed of people who were either illiterate or had limited educations. This work force was augmented by a large influx of immigrants. In either case, the aspiration and expectation levels were keyed to the necessities of life.

One of the original wellsprings for the turnabout in management thought was Elton Mayo's classical Hawthorne studies conducted at the Western Electric Company plant in Chicago between 1927 and 1933.[1] At that time, industrial psychologists and human engineers were stressing the importance of physical conditions on the job to employee performance. Noise, lighting, music, rest periods, ventilation, temperature, humidity—all of these were seen as factors that could improve or impair a worker's performance. The Hawthorne studies originally focused on this area, but were unable to demonstrate any relationship between physical conditions and worker output. The studies were then redirected toward the areas of social conditions, group attitudes, and individual reactions. The two most important conclusions of these lengthy studies were the recognition of the informal organization, and the benefits of participative management. The informal organization has tremendous power to motivate workers—more effectively, in many cases, than the formal organization. Participative management, i.e., being asked for opinions and ideas and being listened to, gives the workers a greater sense of involvement with management.

Soon after World War II our economy transitioned from an industrial to a post-industrial society. New forces came into play, forcing management to reorient its thinking. Some of these forces were the continuing growth of labor unions, the downstream impact of the New Deal legislation passed in the mid-1930s, liberal politicians at the state and national levels and, last but not least, the rapid elevation of the educational level of the workers, who had higher expectations than their predecessors.

During this transitional period many theories were being advanced about human motivation and the basic needs of people. The theory that gained widest acceptance was Abraham Maslow's hierarchy of human needs.[2] His theory was based on two simple premises: People have many needs, and only those needs not yet satisfied cause them to act. Maslow organized his hierarchy of human needs into five categories: physiological, safety, social, esteem, and self-actualization. A superficial understanding of this theory would lead to the conclusion that a

1. Elton Mayo, *The Human Problems of an Industrial Civilization*, 2nd Edition, Boston, Harvard University, 1946.

2. Abraham Maslow, *Motivation and Personality*, New York, Harper & Bros., 1954.

satisfied need is not a motivator of behavior. The fallacy is to view it as a rigid one-step-at-a-time procedure. Each level of needs does not have to be completely satisfied, if that is ever possible, before a person can be motivated by a higher need. Most people are motivated by a combination of many different needs.

Management by objectives (MBO) is a technique introduced in the mid-1950s to resolve the alienation of managers and white-collar workers, who felt there was a conflict between their personal goals and those of the organization. The term MBO, as a management principle, was first used by Peter Drucker in his book, *The Practice of Management.*[3] The three essential elements of any MBO program are definition of the starting point, specification of the finishing point, and a stated time when the identified goals have to be achieved. Successful implementation of MBO is based on three assumptions about the participants: They will take responsibility for goals that they help structure; they are capable of effectively organizing their day-to-day work; and they are goal-conscious and interested in self-advancement. Based on these assumptions, it is evident that MBO is not universally applicable. Furthermore, it should never be viewed as a way to extract from workers promises that can later be used against them. Management by objectives is not a substitute for good management.

The "carrot and stick" theory of motivation was still alive and well. Douglas McGregor, in his book *The Human Side of Enterprise*, categorized a certain set of assumptions that underlies most managers' thinking.[4] He summarized these assumptions as the authoritarian approach under the label of Theory X:

—The average human being has an inherent dislike of work and will avoid it if he can.

—Because of this human characteristic of dislike of work, most people must be coerced, controlled, directed, or threatened with punishment to get them to put forth adequate effort toward the achievement of organizational objectives.

—The average human being prefers to be directed, wishes to avoid responsibility, has relatively little ambition, and wants security above all.

In the same work, McGregor summarizes the assumptions of the participative approach regarding the individual under the label of Theory Y:

—The expenditure of physical and mental effort in work is as natural as play or rest.

—External control and the threat of punishment are not the only means for bringing about effort toward organizational objectives. Man will exercise self-direction and self-control in the service of objectives to which he is committed.

—Commitment to objectives is a function of the rewards associated with their achievement.

3. Peter Drucker, *The Practice of Management*, New York, Harper & Bros., 1954.
4. Douglas McGregor, *The Human Side of Enterprise*, New York, McGraw-Hill, 1960.

—The average human being learns, under proper conditions, not only to accept but to seek responsibility.
—The capacity to exercise a relatively high degree of imagination, ingenuity, and creativity in the solution of organizational problems is widely, not narrowly, distributed in the population.
—Under the condition of modern industrial life, the intellectual potentialities of the average human being are only partially utilized.

The assumptions behind Theory X emphasize authority; the assumptions behind Theory Y emphasize human growth and self-direction. In relation to Maslow's hierarchy of human needs, Theory X emphasizes physiological and safety needs but tends to ignore the higher-level needs. Theory Y, however, emphasizes social, esteem, and self-realization needs rather than the subsistence needs.

A cursory interpretation would lead to the conclusion that Theory Y is the polar opposite of Theory X. McGregor did not intend that the two sets of assumptions represent opposite extremes. His central principle of Theory Y is that of integration: the creation of conditions whereby members of the organization can best achieve their own goals by directing those goals toward the success of the enterprise.

Management thought evolved to the point that there was a realization that task orientation and social interaction are not mutually exclusive. Robert Blake and Jane Mouton utilized this concept to describe managers on a two-dimensional managerial grid of task and people orientations, rated on a scale of 1 to 9.[5] On the managerial grid, a 1,1 manager is a nothing, low on both concerns. A 1,9 is a country-club type, concerned only with people and morale, not performance. A 9,1 is a task-dominated slave-driver and autocrat. The model of excellence is the 9,9 manager who is greatly concerned with both people and task. Under this combination, effective integration of people with production is possible by involving them and their ideas in determining work conditions and strategies. The major contribution of this management model is the recognition of the validity of the middle-path compromise position of the 5,5 manager. This middle-of-the-road management philosophy recognizes that adequate organization performance is possible through balancing the necessity to get out work, with maintaining morale of people at a satisfactory level.

Frederick Herzberg pioneered some of the early efforts to learn about task satisfaction and motivation. His two-factor theory of job motivation, satisfiers and motivators, culminated in his motivation-hygiene theory.[6] The hygiene factors or satisfiers include company policy, supervision, working conditions, inter-

5. Robert R. Blake and Jane S. Mouton, *The Managerial Grid*, Houston, Texas, Gulf Publishing, 1964.
6. Frederick Herzberg, *Work and the Nature of Man*, Cleveland, World Publishing, 1966.

personal relations, money, status, job security, and personal life. The absence of these factors may lead to dissatisfaction; however, the presence of these satisfiers will not motivate people to work any harder than the minimum necessary to hold the job. To draw out the extra effort, the employee has to be offered an opportunity to satisfy higher-level needs for power, autonomy, competence, and achievement. The motivation factors are mainly aspects of the task; for example, achievement, recognition for accomplishment, challenging work, increased responsibility, growth, and development. The presence of these factors may motivate some people to extra effort; ironically, their absence will not bother most people. The basic criticism of Herzberg's theory is that it is not always replicated by research because it is too general and ignores differences between people's expectations.

What we really need to do with work, Herzberg suggests, is to enrich the job. Job enrichment means deliberate upgrading of responsibility, scope, and challenge. The job-design continuum starts on the low side with rotation and extension, then progresses to the high side with enlargement and enrichment. The continuum implies that there is greater variety, more responsibility, and increased opportunity for personal growth as one progresses toward the enrichment side of the scale. The continuum job terms can be defined as follows: Rotation—periodically reassigning the employee to new tasks; extension—giving the employee additional duties requiring the same skill level; enlargement—making each employee's assignment a larger part of the total work process; and enrichment—giving the employee full responsibility for an entire process.

Job enrichment often involves more participation by the employee in decision-making, and responsibility for planning and inspecting, as well as doing. Some of the roadblocks to job enrichment programs are managers who resist the apparent threat to their authority; employees who show little interest in taking on new jobs; and labor unions that see the program as a scheme by management to get more work done for less money. Job enrichment is still one of the most commonly suggested cures for employee alienation and job dissatisfaction.

A natural extension of job enrichment is the autonomous work group. This progression from the individual job to the group is probably due to the fact that the individual's job cannot be enlarged or enriched without reorganizing the work of the whole department or process. The autonomous work groups are result-oriented groups of workers, often largely independent of external controls or influences for substantial periods of time. They are usually responsible for the assembly of a complete unit or sub-unit; they may also be responsible for quality inspection, organizing and planning their workload, and equipment maintenance. The members of these groups are usually trained to perform all or most of the tasks carried out within the group, each of which could be viewed as a mini profit-center. The basic disadvantage of these work groups is that they may increase the cost of doing business; for example, retooling, redesigning the plant,

providing extra floor space, and increasing capital investment.

Another innovative approach is participative management, which changes the conventional manager and employee relationship. It allows employees increased influence in the overall direction of the organization. True participative management makes employee inputs a natural part of the process of conducting the organization's business. Unique is the manager who has knowledge of all alternatives and consequences related to the decisions that he must make. Because of barriers to the upward flow of information, much valuable data possessed by subordinates never reaches top managers; participative management tends to break down these barriers. The continuum for participative management extends from a simple suggestion box all the way up to having a union official sitting on the board of directors.

Another participative-management concept gaining in popularity is referred to as either "quality circles" or "labor-management participation teams." Under this concept, problem-solving is a joint venture in which management and labor unite for the common good. This concept recognizes that the workers have more knowledge than anyone else about some of the technical issues and can make valid contributions to the problem-solving process. Regardless of the participative-management technique used, the quality of participative management should always be considered more important than the volume.

Modern organizations are confronted, more than ever before, with the need for change arising from new technologies, changing market demands, and obsolete labor skills. There is a built-in resentment or resistance to these types of changes, i.e., giving up the familiar, the sense of helplessness, loss of marketable skills, and future uncertainty.

A future-oriented approach that deals directly with the resistance to change is organization development (OD),[7] a process of planned change involving behavioral science techniques designed to build a more effective organization. Organization development is a long-range effort and utilizes behavioral science consultants or change agents as the catalyst. The change agents concentrate on creating an open-minded, flexible organization receptive to change; employees can recognize the need for change and help initiate and implement the required actions. Initially, the change agent helps the individuals to plan for change and to bring it about. Unlike traditional training methods, OD concentrates on the total organizaiton, rather than on individual development; it focuses on organizational, group, and interpersonal processes. The main disadvantage of organization development is that its potential cannot be demonstrated without the entire involvement of the total work group. Organization development is a technique that cannot be imposed; it requires a cooperative effort.

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7. Warren G. Bennis, *Organizational Development*, Reading, Mass., Addison-Wesley, 1969.

Another innovation is flexible working hours. There are many approaches to the concept, the most common being the flextime system in which employees may arrive for work at any point within a 2-hour time span, adjusting their lunch breaks and departure times accordingly. The system has certain core periods in the middle of the day when all employes must be present. For other than the core period, flextime allows employees to adjust their working hours to the needs of their personal lives.

Staggered hours, a conservative variation of flextime, requires the employee to choose a fixed daily arrival time in advance. On the other extreme is the variable-hours system that involves no core period during the workday, allowing employees to choose whatever eight hours they prefer.

After trying for 30 years to develop a single theory to explain the values, needs, and motivations of workers, social scientists in the late 1970s admitted that what is important to understand about American workers is their diversity. There are many reasons why people work, many rewards they derive from working, and many sources of discontent.[8] Each individual has a unique combination of work value, attitudes, needs, and desires. This realization may provide insight for the demise of the American universal principles-of-management concept. For years scholars and practitioners felt that the principles of management were universal, and that they applied everywhere; increasingly, they recognize that American management principles do not work everywhere and are not universal.

As our post-industrial society progresses from a service society to an information-processing society, our work ethic will probably evolve to: "Work smarter, not harder." This could be one of the major attributes of our emerging work force.

This ascent of human relations and organizational-development management does not signal the end of scientific management. That would entail an unlikely and undesirable loss of valuable tools for accomplishing work. The effective manager of the future will integrate the human relations and scientific techniques as complimentary components of a synergistic work environment.

In considering ways that make work more satisfying, the manager should never forget that society cannot tolerate approaches that will seriously undermine the economic effectiveness of organizations in order to increase employee satisfaction. The lessons learned in the '70s by the basic American industries attest to the validity of this principle.

8. James O'Toole, *Working: Changes and Choices*, New York, Human Sciences Press, 1981.

European Overview Part II: Comparative Investment Patterns

14

Dr. Franz A. P. Frisch

In Part I, I tried to explain the subtle and not-so-subtle causes for "European Behavior." In particular, I explained the differences in the views toward profit and the impact of labor stability on the behavior of the European industrial firm.

In this part we will look at the investment patterns that prevail in European and American industry, particularly defense industry. I will first explain the causes of the difference in American and European investment patterns and its consequences for defense investment. Second, I will discuss the impact of depreciation time on defense investment, and, finally, I will address the disincentive toward investment for defense represented by the profit cap.

Reasons for Investment

"Why are companies in Europe and the United States investing in defense industry?" The superficial answer, of course, is to make money. But less superficially, they are doing it in Europe and the United States for entirely different reasons: In Europe, they *must* do it in order to satisfy the market by amploying a stable work force. In the United States, they *may* do it for competitive reasons. There are thus two different causes with the same outcome.

As before, we will discuss this through the use of linearized conceptual models, suppressing the *de facto* non-linearity of most techno-economic behaviors. (We must remember that none of the economic explanations in this paper are intended to be more than simple conceptual models of a very complex reality.)

We start our analysis with the assumption that both an American and a European company have the opportunity to compete for a contract © to deliver N_C units in the contract time T_C as sketched in Figure 1. We also assume that both parties start out with the same production method which is in turn determined by the same initial investment I_o and the same labor elevation α_o. Contract time T_C and contract quantity N_C are considered as requirements. What this means to the American and the European company is sketched in Figure 2.

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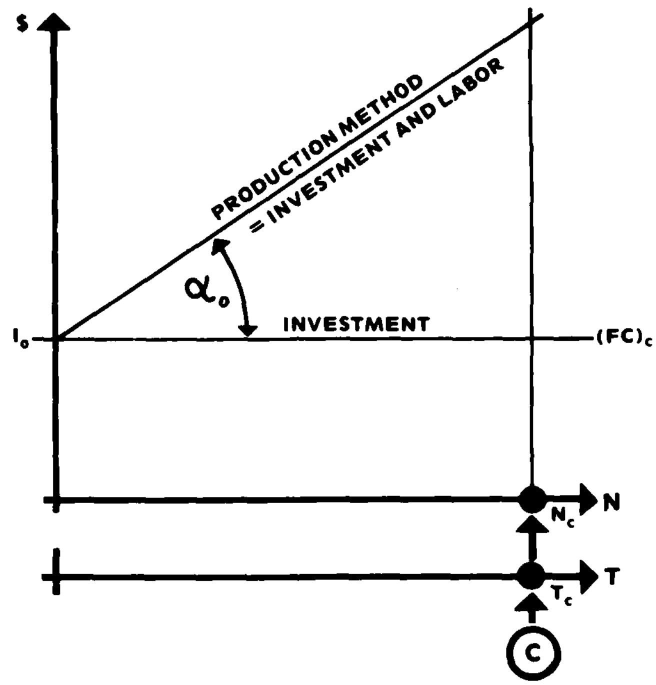
FIGURE 1
Contract Assumption

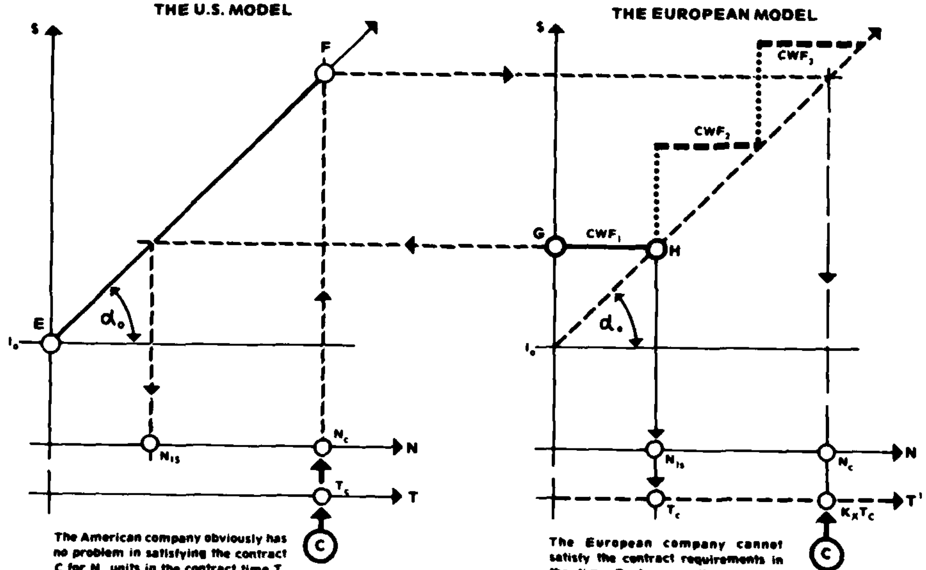


Two horizontal axis are shown—one for the quantity N and one for the time T. The scales are selected in such a way that N_c corresponds with T_c. The figure describes the uniform assumption for the U.S. model and the European model.

The European, however, or so we assume, is not willing to forgo the contract opportunity and hence searches for a way to satisfy the contract time T_C while keeping his labor force constant. The only way to do this is to search for a new labor elevation α_1 (instead of α_0; this however, will only be possible through an additional investment ΔI on top of I_0. In short, he improves the manufacturing process through investment. This is illustrated in Figure 3.

The European *must* invest in order to satisfy the contract time—the American has no need to do it. However, as by-product, the European finds out that by investing, he can not only accommodate the time requirement of the contract, he can also decrease the cost by ΔC and gain a favorable competitive position. This, of course, does not remain unnoticed by the American counterpart, and he tries

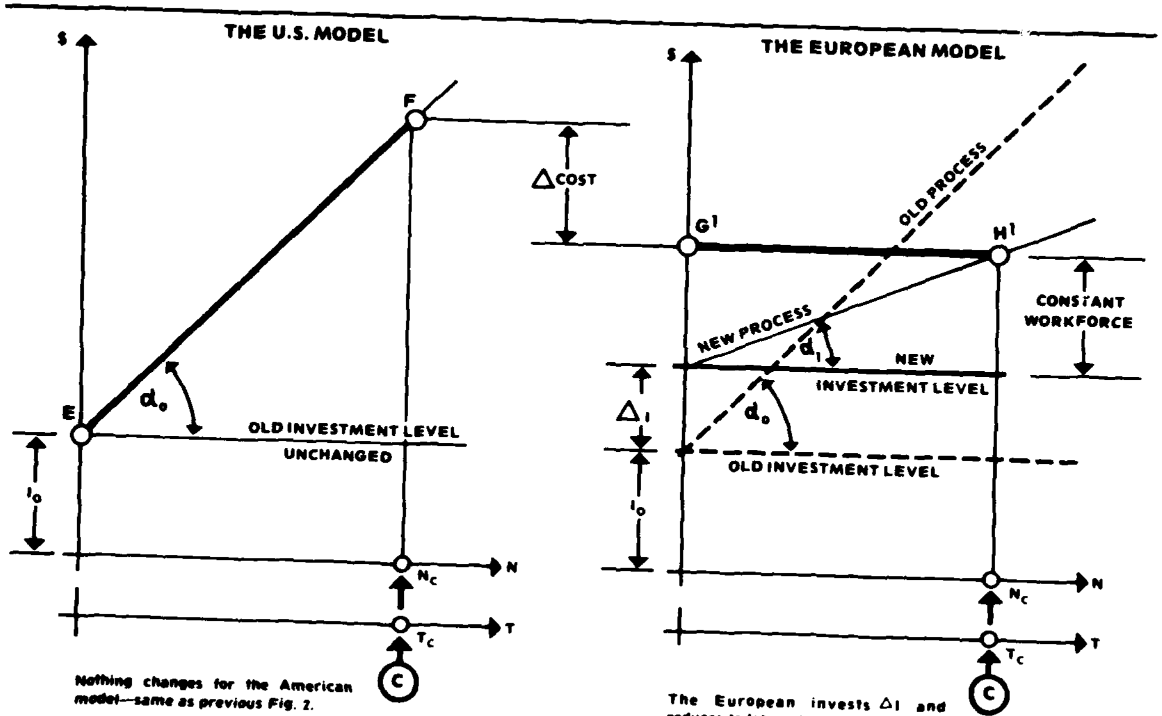
FIGURE 2
Contract Execution and Constraints



The American company obviously has no problem in satisfying the contract C for N_c units in the contract time T_c because labor is a proportional element and labor for a second and third shift can be hired for the available contract, as shown with the line EF.

The European company cannot satisfy the contract requirements in the time T_c because the company works with a constant workforce, indicated with GH, and can only deliver in the contract time T_c the amount appropriate to one shift N_{1S}. (Note that the scale T' is different from the scale T for the American counterpart). The execution of the total contract would take a multiple of T_c, indicated with $k \times T_c$. CWF_1 indicates the constant workforce for one shift, CWF_2 the second turn with the same workforce, and CWF_3 for a third repetition with the same workforce.

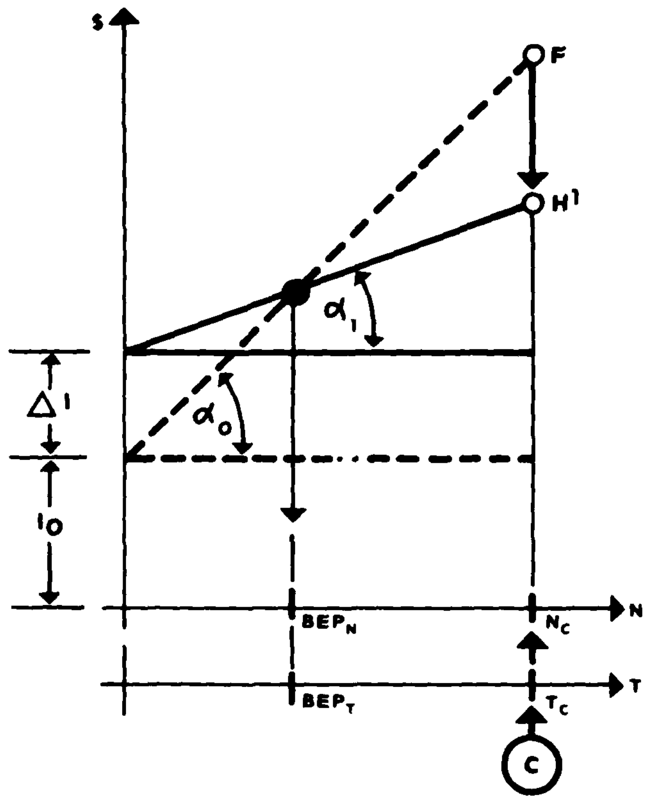
FIGURE 3
Equalization of Capabilities



Nothing changes for the American model—same as previous Fig. 2.

The European invests ΔI and reduces to labor elevation from α_o to α_1. With this, he has synchronized the N and T axes and satisfy the contract in the Time T_c with the constant workforce CWF at the level G^1H^1

FIGURE 4
Equal Result



Both the American and the European company have invested and changed the labor elevation from α_0 to Δ_1. The old system (dotted lines) and the new system are identical and have break-even points for quantity (BEP_N) and time (BEP_T) and both have reduced the cost from F to H^1 and both can satisfy the contract C in the contract time T with the contract quantity N.

to gain the same cost advantage by investing like the European company. With this step, not only the capabilities, but also the cost, are equalized, and, again, one single model serves the American and the European partner as shown in Figure 4. From a purely engineering point of view, both the American and the competing European systems are made equal.

Depreciation and Replacement Time and Cost

Now you may think both the American and the European systems are equal. Unfortunately—to use an old cliché—some are more equal than others because of the differences in the tax system.

The problem for the American company appears in all contracts where the contract time T_C is shorter than the depreciation time T_D for all assigned investment (as defined below). For the European company, the difference between T_C and T_D is a non-problem because, first, in many European countries the depreciation allowance for the first year is up to 100 percent (in Japan it can be almost 200 percent) and second, defense contracts are normally of longer than a 1-year duration.

We restrict our consideration here to *assigned investment* (or assigned facilities and equipment), which we may define as any investment made in order to facilitate a specific defense contract, whereby such investment has "technical use value" beyond the contract time, but no "economical value" if no other (similar) defense contract is forthcoming. From the investor's point of view, assigned investment may be the same as *dedicated investment*, defined as any investment that has technical use value only in the context of a specific contract for things like jiggs and fixtures. The problem is sketched in comparative form in Figure 5.

Since no further problems exist for the European company, we will continue with the U.S. model only and will show what happens to the American company when it is trying to recuperate, like the European, the assigned investment in the time frame T_C. This is illustrated in the three-picture series of Figure 6.

I have introduced in Figure 6 the new term of "simulated investment," which I define as the planning goal toward which any investment must be recouped if it is to retain its original earning or purchasing power. If conditions do not permit the accumulation of capital toward the simulated investment, the "value of capital" deteriorates because it subsidizes fictitious prices, which are prices below true cost.

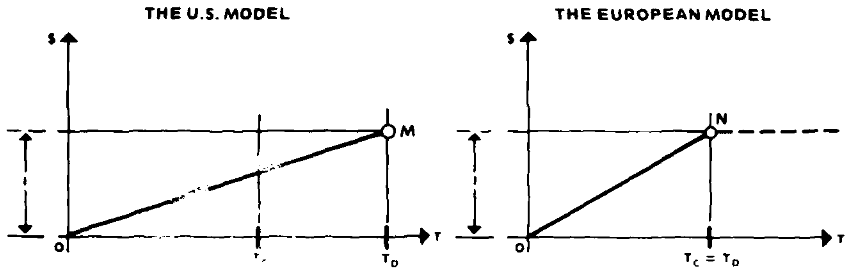
The capital recuperation develops into an even more severe problem if we substitute replacement cost for investment cost, and apply the capital accumulation toward replacement cost rather than relating it to the original investment amount. This is sketched in Figure 7.

Profit Cap

Considerable differences between the American and the European views exist not only with regard to the profit definition but also with regard to the amount of profit related to a defense contract.

The Europeans are neither overly concerned with profits from defense contracts nor with the idea of competition for defense contracts. The Europeans look

FIGURE 5
Time Comparison



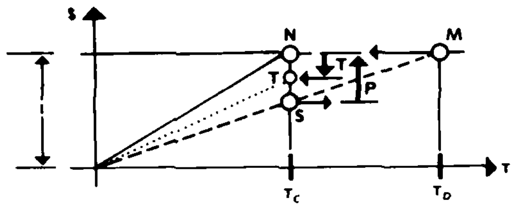
The depreciation time T_D is larger than the contract time T_C and according to the American company can re... its investment I only along the time D... without paying tax for "profits."

For the European company, T_D equals T_C (or even $T_D < T_C$) and therefore, it is no problem to recoup the dedicated investment in the contract time, T_C

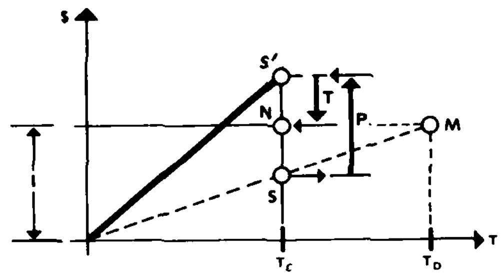
at defense industry almost as at a GOCO operation (government owned, contractor operated), or as a captive arsenal operation with little relationship between the military and the civilian sector of manufacturing. Everything necessary to make the "quasi" arsenal operation self-sustained on a permanent basis is accepted in Europe as "permissible and allowable cost"; no profit is needed, and if one is made, it is most ruthlessly taxed away. This has its spillover to the European view toward productivity. For the European, productivity is not a goal in itself—it is the result of doing things right. And doing things right means searching for the particular investment level that, when combined with a constant work force, produces a military system at the minimum cost. Minimum cost means systems cost in the broadest sense: cost of the hardware proper, plus impact cost of employment and unemployment, plus impact cost of capital provisions. Within this total system, the military goods or hardware is only one of many subsystems and hence not unnecessarily subject to rigorous sub-optimization.

For the American, military industry is conducted on a competitive basis like any other industry in the marketplace. This view is combined with strict regulations of what "allowable costs" are and how much profit a defense contractor should be permitted to make on a contract, whereby profits are often couched in terms of various formulations of incentive fees. It is expected that the defense contractor covers all its "non-allowable costs"—but which are still true costs for him—out of profit, as in any other commercial enterprise. Only commercial enterprises have no profit cap and can generate sufficient profit, provided the market permits doing so. The defense contractor, however, has to cover his non-allowable cost from a constrained or fixed profit of approximately 10 percent on the total contract. The American defense contractor can work with this con-

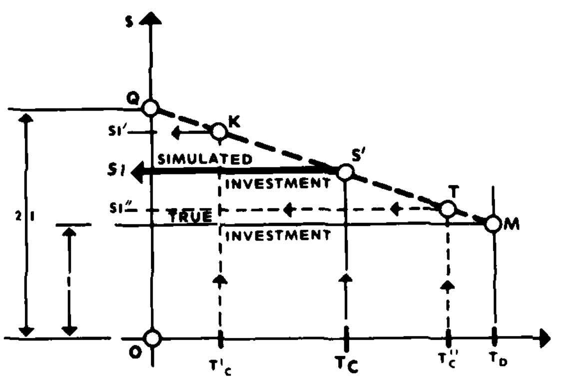
FIGURE 6
Simulated Investment for Time



The American company accumulates Capital I toward point N like its European counterpart. The tax law, however, permits only *the recoupment* of capital toward S. Therefore, SN is declared as profit P from which tax T has to be paid, with the result that the capital element NT cannot be recouped.



If the American company really wants to recoup its investment I during the time T_C, it must accumulate capital toward point S^1 with $SN = S^1N$ (for the 50% tax bracket). Then the "profit" P is 2x(N-S); it pays 1x (N-S) on tax T and ends up on point N like its European counterpart (Fig. 5), which has not paid any tax.

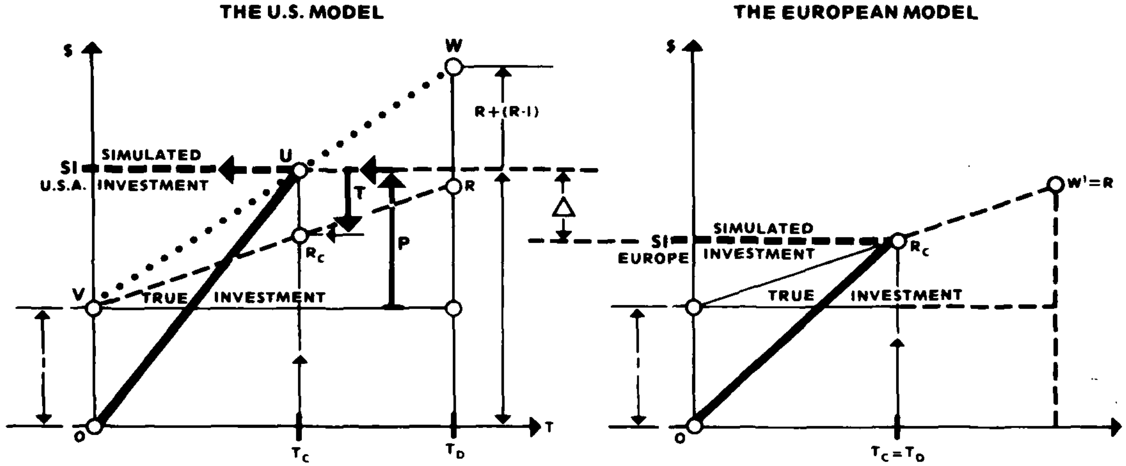


The American company must accumulate capital toward S^1 and deal with this amount as "simulated investment" SI. If the contract time were $T_C{}^1$ or $T_C{}^{11}$, *the simulated investment* would be SI^1 and SI^{11} respectively. However, in all conditions where T_C is shorter than T_D, the simulated investment SI is larger than the true investment I.

straint, provided he keeps his capital investment low and uses labor-intensive methods, which he can do, because for him labor is a proportional and not a fixed-cost item. Let me explain this on an example, keeping in mind that profit is measured against the total contract.

FIGURE 7

SIMULATED INVESTMENT FOR REPLACEMENT



If the American company wants to accumulate capital towards the replacement value R in the time T, it must accumulate capital toward the simulated investment U and declare IU as "profit"; after tax the company retains the capital R_C, the replacement value at the time T_C under its control. The level of the simulated investment moves as a function of the difference between T_C and T_D along the line VW.

The European company can accumulate tax free within the contract time T_C capital toward the replacement value R_C and hence the simulated investment moves along the line VW^1 as function of the contract time T_C.

Let's assume an American company has a total contract amount of $100 million (excluding profit). If we permit a 10 percent profit on the contract, the profit will amount to $10 million, and the 10 percent, or the $10 million, shall be the "permissible profit" or the profit cap of the contract. Let's further assume that the contract of $100 million (before profit) will be the result of employed labor (L) and employed capital (C), and that the company can select for this specific contract two distinct manufacturing methods that cost the same except that one method is labor-intensive and the other is capital-intensive:

	Method 1		*Method 2*
(L)	$80 million	(L)	$20 million
(C)	$20 million	(C)	$80 million
Cost	$100 million	Cost	$100 million
Profit	$10 million	Profit	$10 million
Price	$110 million	Price	$110 million

For the customer, it makes no difference whether the company chooses method 1 or 2. In both cases the price will be $110 million at the product quantity *n*, for which both methods will operate at the break-even quantity (as assumed). However, there is quite a difference for the company. With method 1, the return on investment is 10/20, or 50 percent; with method 2, it is 10/80, or 12.5 percent. Of course, the American company will lean toward method 1, while this consideration is nonexistent for the European counterpart—as long as he can hold his work force constant.

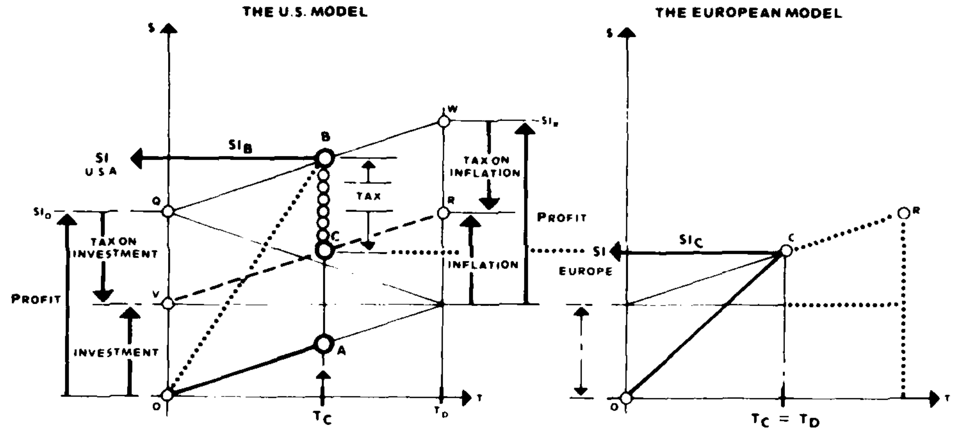
Management Decisions

If you manage a defense project in the NATO environment, you will frequently observe that American and European managers respond with different management decisions to generically identical problems. In order to understand the reasons for these differences, we must integrate all the elements we have discussed so far: (1) the profit cap, (2) the simulated investment for (a) the contract time and (b) the replacement cost, and (3) the configuration of the labor cost, which are constant in Europe and proportional in America.

The consideration of the simulated investments because of time (Figure 6) and because of replacement cost (Figure 7) are combined in Figure 8. Having determined the simulated investment—I repeat, it is this particular level toward which capital must be accumulated in order to cover non-utilization (of assigned) investment and to cover the inflation (for replacement)—the "cost picture" of the American and European operation takes the form sketched in Figure 9.

The difference between true cost and conceptual cost must be covered by the "permissible profit" for the American company and—this is the point—the permissible profit is calculated against the conceptual cost. On the other hand, the profit in the American tax system is supposed to cover the difference between the

FIGURE 8
Total Simulated Investment



(1) If $T_C = O$, the entire investment I must be recovered out of an after tax profit $P = I$. In order to do this, capital must be recovered toward SI_O and $SI_O = P$ before tax. This I call the "investment tax."

(2) If capital is to be accumulated toward the replacement cost R at the depreciation time T_D, then this must be covered by profit P after tax. Hence, tax must be paid on inflation in order to arrive at R and a simulated investment of SI_R is determined. This we may call the "inflation tax."

(3) The behavior at contract time T_C is the geometric combination of the condition at $T_C = O$ and at $T_C = T_D$ (under a simplified linear assumption). This leads to a simulated investment of SI_B for the American company.

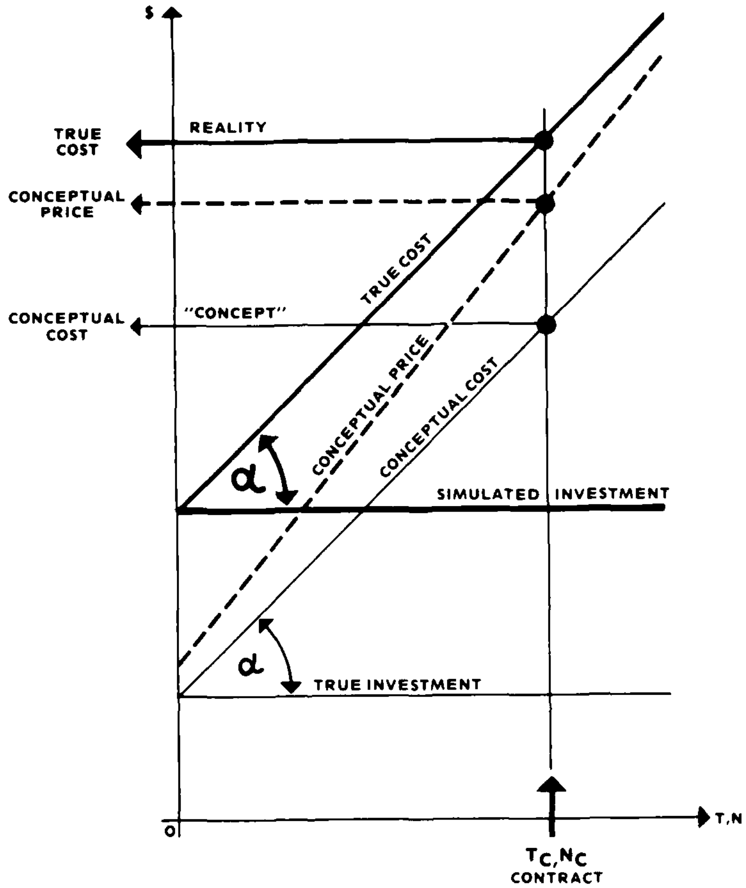
(1) Not applicable because of acceptance of $T_C = T_D$ for the European company.

(2) Not applicable because the replacement cost R is a before tax cost and not a part of profit.

(3) Not applicable because the European can, without paying any tax, accumulate capital toward the replacement value C at the contract time T_C and works therefore with the simulated investment SI_C.

LINE OA Permissible capital accumulation for the U.S. company during the Contract time T_C
LINE OB Necessary capital accumulation for the U.S. company in order to have after taxes the net capital along the line OC at hand
LINE OC Permissible and necessary capital accumulation for the European company
LINE BC Tax Burden for the U.S. company

FIGURE 9
True Cost



true cost and the conceptual cost. If and only if the permissible profit leads to a conceptual price that equals the true cost, the American is operating without loss of substance according to the rules of the preservation of earning power (see Part I). If, and only if, the permissible profit exceeds the true cost, a true profit for the American company exists; if this is not possible, the American company loses substance.

The permissible profit now turns the problem for the American defense contractor completely around and the question to be asked is: *How must the American defense contractor invest in order that the permissible profit covers the true cost?* The answer is given in Figures 10, 11, 12, and 13, where, in pictorial steps, the problem is unfolded from its end, working forward toward the solution. Please keep in mind that the profit (in Figure 10) is *necessary* for the American company, but only *convenient* for the European company.

As the next step, the American company will ask, "What investment can I make in order to survive with the permissible profit?" The American company suddenly equates the permissible profit with the necessary profit. The European now will ask, "How much do I have to invest in order to satisfy the contract with my constant work force?" This step is sketched in Figure 11. If we bring the determination of investment (Figure 11) back to the concept in Figure 29 (Part I), we close the circle of the thinking process and portray the resulting American and the European production method in the classical way as shown in Figure 12, the linearized concept comparison.

You will notice that we started with the analysis in Figure 10 with the same price and the same true cost for the American and European company, and we end up with different costs C^1 for the American system ($C_A{}^1$) and for the European system ($C_E{}^1$). This means, most bluntly expressed, that the cost comparisons with which we are familiar are utterly meaningless, because we are here comparing incomparable concepts.

In these comparisons I have assumed that the two labor elevations α_A and α_E will produce, together with the two investment levels I_A and I_E, the product requested in the contract. Unfortunately, this is not necessarily the case. Next, in Figure 11, I do not show the iterative search process for the American model and may have therefore misled you by implying a simplicity that does not exist. I am fully aware of the short cuts I have used in the exposition of the problem, but I have neither distorted the reality of the problem nor the possibility of deducing the different management decisions with regard to the execution of a defense contract in the United States and in Europe:

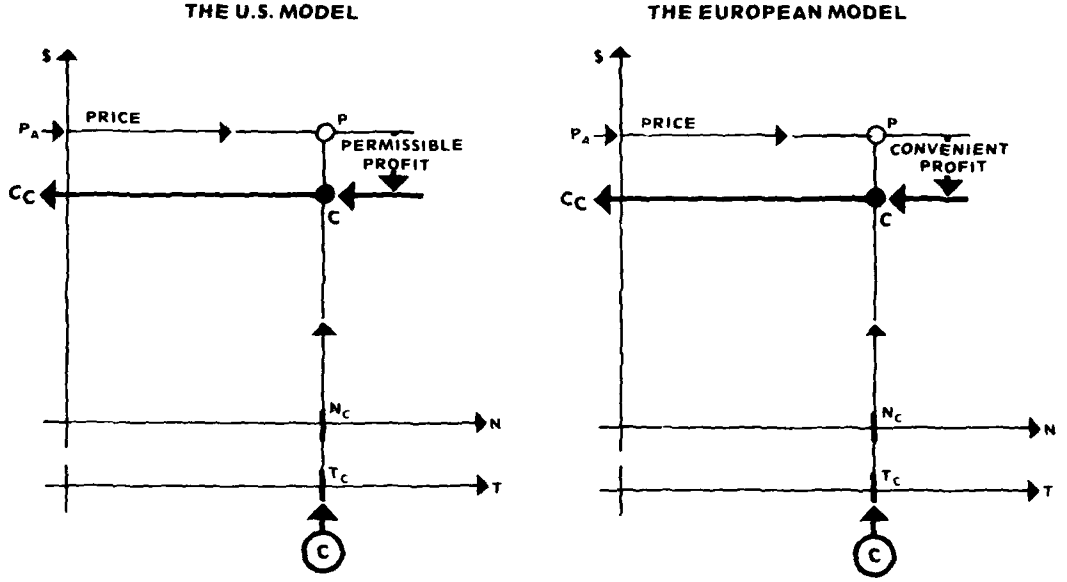
—The European manager will resist any time pressure in the contract if such time pressure would mean an increase in the work force beyond his standard complement of workers.

—In turn, the European managers will consider the delivery time as the result of proper employment of capital and workers and not as the requirement.

From this follows the European view that productivity is what you get if you employ workers and capital optimally; productivity is not a goal, but a result.

—The European manager will be willing to invest any amount for a defense contract provided he can keep his work force stable and does not bring himself out-

FIGURE 10
The Start From The End

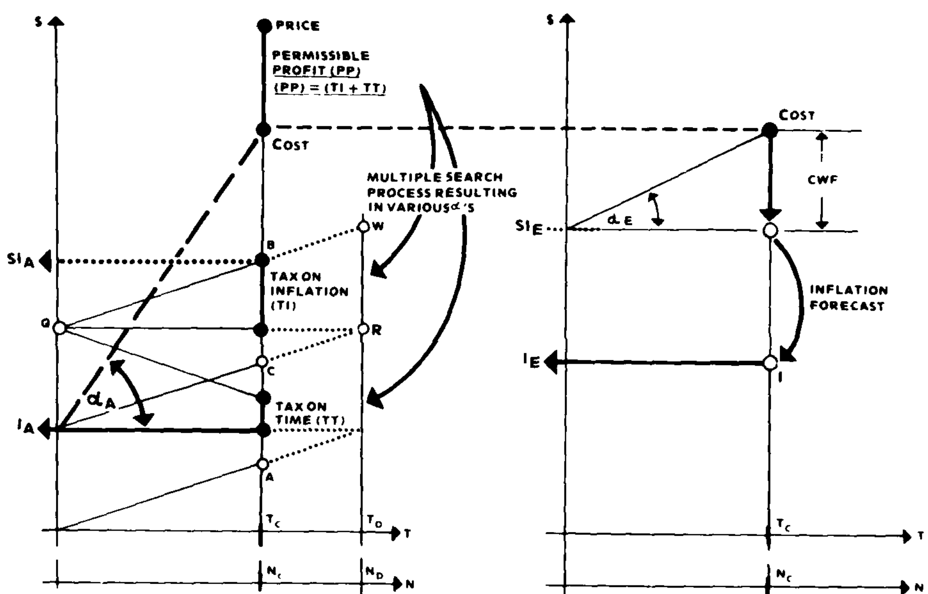


Both the American and the European company are going for the same contract C, to deliver N_C *units in the contracted time* T_C. The marketing departments of both companies *have determined* what an acceptable price, P_A for the contract *might be. In addition, the* American contractor (and this is known to both parties) can only accommodate about 10 percent profit in his price. Assume that the European company *goes along* with this constraint and both establish point C, or the cost ceiling C_C. *Both companies* must operate within this cost ceiling.

FIGURE 11
Determination of Investment

THE U.S. MODEL

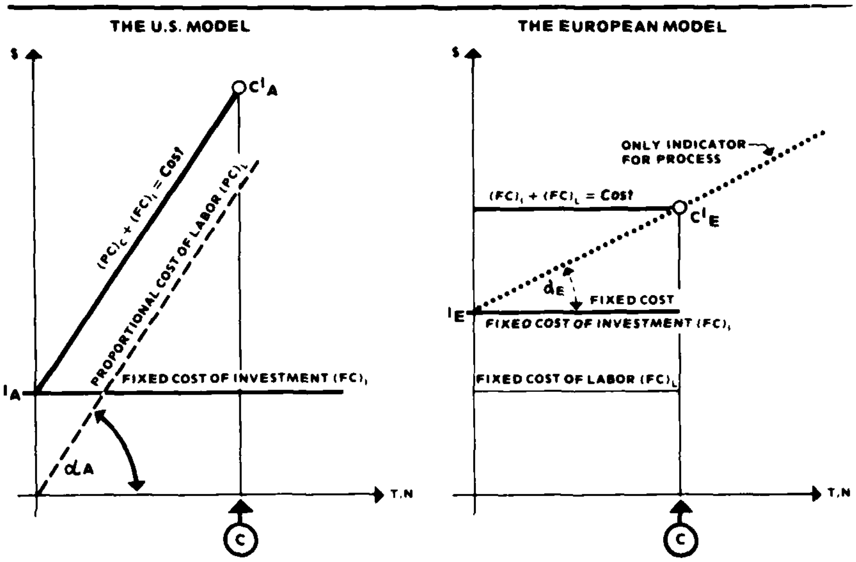
THE EUROPEAN MODEL



The American company searches for this investment level I_A, where the permissible profit on capital plus labor is able to cover the tax on time and the tax on inflation (see Fig. 12). The simulated investment SI_A and the true investment I_A is the result of the search. The labor elevation α_A, is a coincidental result, plotted above the investment I_A.

The European company starts at point C and goes down the distance CWF (the cost of the constant work force) and arrives immediately at the simulated investment SI_E (point R) From R (the replacement value) the inflation is deducted and true investment I arrived at The labor evaluation α_E is a coincidental result, plotted above the simulated investment SI_E

FIGURE 12
The Concept Comparison



In both cases, the true investment is plotted as the fixed cost (because of capital). In the American model, the variable labor cost (with the elevation α_A) is added to the fixed cost (of capital). In the European model the fixed labor costs are added to the fixed cost of capital. For the contract C, this leads to the "fictitious cost" C_A' and C_E' for both sides.

side of the competitive range. From a strict investment point of view, for the European, investment in the defense industry might be as good as any other investment opportunity, because the preservation of the capital's earning power is secured through the tax structure.

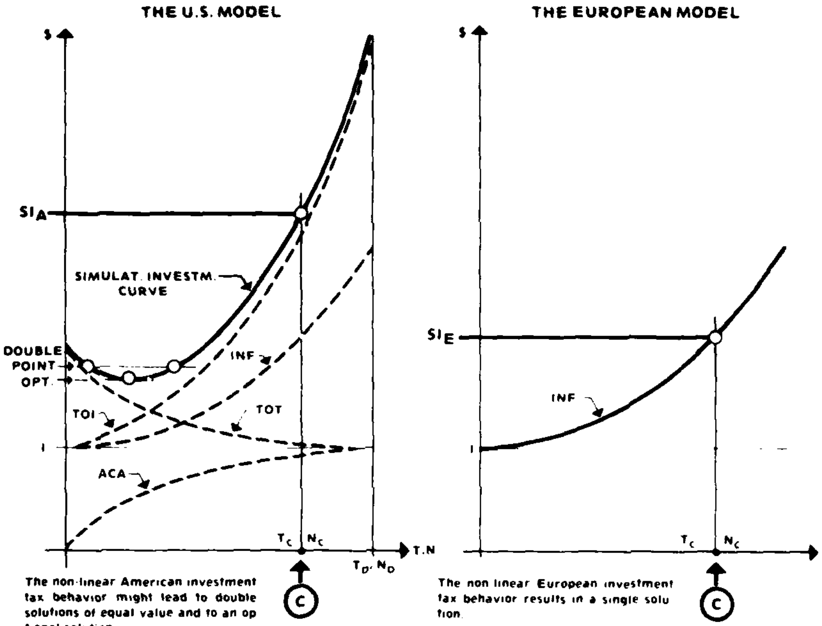
In contrast:

—The American manager will only invest in the defense industry the absolute minimum, because he has to cover all real but non-allowable costs out of a restricted profit.

—In turn, the American manager will search for the most labor-intensive production method in order to achieve with a restricted profit a satisfactory after-tax return in his investment.

—The American manager will search to stretch any contract to the utmost in order to bring the contract time as close as possible to the allowable depreciation time.

FIGURE 13
Non-linear Behavior



The non-linear American investment tax behavior might lead to double solutions of equal value and to an optional solution.

The non linear European investment tax behavior results in a single solution.

I = Investment
ACA = Accelerated Captial Accumulation
INF = Inflationary increase of replacement cost
TOI = Tax on Inflation
TOT = Tax on Time
SI = Simulated Investment

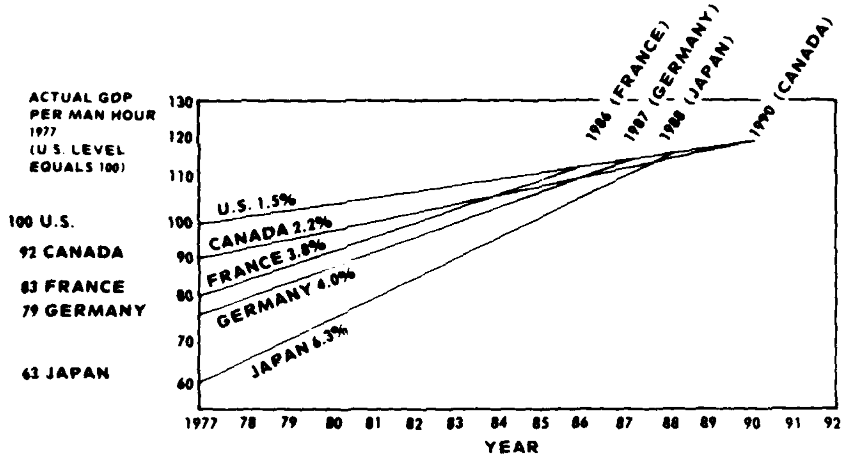
Add to this the differences in the training level of the work force, the differences in financing, and the difference in the government-industry relationships, and a pretty complete picture will emerge of what to expect when working with European defense industry.

In closing, let me portray the last figure series (Figures 10 through 12) in a non-linear form. This is shown in Figure 13.

STATISTICAL INTERPRETATION AND COMMENTS

In Parts I and II, I have attempted to show the significant differences in American and European views toward competition, education, and taxation. This, however—remember the caveat in the introduction—does not mean that one party is smarter than the other. It only means they are different. They are not

FIGURE 14
Manhour—Productivity



AVERAGE ANNUAL GROWTH RATE OUTPUT PER EMPLOYEE HOUR
BASED ON ACTUAL OUTPUT LEVELS IN 1977 AND PROJECTED PRODUCTIVITY GROWTH RATES

only different in their cultural backgrounds, but also in their appearance of the structure of the economy. We can observe this in the ratios between the productive work forces and the service work forces or in the ratio of the agricultural to the non-agricultural population.

The differences are embedded in the relative smallness of the European sovereign countries compared to the United States; in the essential absence of an agricultural European industry for the sake of the family farm; in the European poverty of natural resources; in the density of the population, and hence proximity of town and country; in the infrastructure and transport systems; and so forth almost *ad infinitum*. But all those differences are interdependent, and it is almost impossible to separate cause from effect. Furthermore, a series of catastrophies has molded Europe: first, the falling apart of the economically self-sustained and well-balanced Austria-Hungary monarchy after World War I into many originally non-viable economic splinters; and, 30 or so years later, the destruction of European industry, first by German guns and later by Allied bombers during World War II. Europe had to adapt and had to learn to live with facts, where nothing might be more descriptive than the unreality of the Austrian republic after WWI and its perfect adaptation to smallness after WWII. During the first period, Austria was still under the illusion of imperial grandeur and failed; in the

second period, it learned to accept smallness and made out superbly, currently with the lowest inflation rate (3.5 percent) and the lowest unemployment rate (1.5 percent) in Europe.

Maybe all this can be highlighted with a few statistics.

Productivity

Any conversation about Europe (and Japan) quite frequently starts with a discussion about productivity and with a statement that the American economy shows decidedly less growth than the European economy. This statement is definitely correct, but so is the statement that "a young dog grows, but not an old one." And at this moment, the American economy is the old one. It still has the highest relative productivity of any country in the world, as Figure 14 shows, while the other developed nations are approaching the U.S. level of productivity. This does not necessarily mean, however, that the others will surpass American productivity or that productivity can be increased without limits.

It appears that in mature industry a rather stable level of productivity will develop—major breakthroughs excluded—and it may be a matter of preference, but not of substance, if such levels are designated with "stability" or with "stagnation." But it is a matter of substantial difference whether an industry works for the indigenous market within the system or for foreign markets, which is the environment of sovereignty. In the first case, unemployment might be created within the domestic system, while in the second case, unemployment might be exported into the environment. Table I illustrates this point (valid for 1979).

If one is further aware that the GNP of the developed nations outside the United States is approximately evenly divided between production and services, then one can understand (without being too far off target) why at least some of the European Economic Community nations must produce, in certain industrial sectors, about 50 percent of their goods for export. Exporting is, for many European countries, the backbone of the operation while it is, with few exceptions, only a marginal nuisance for most American companies; only the U.S. agricultural industry might depend on export. In turn, economic rules of production for export do not have to be the same for indigenous consumption. The goal of the export-dependent industry might be the search for productivity that results in minimum cost, while for the non-export-dependent economy, the goal might be a combination of maximum employment and bearable cost. For example, an industry that produces predominantly for export might employ automation and robots to the utmost, provided this helps to make the exported goods competitive. On the other hand, an industry that produces exclusively for the domestic market might rather serve as a source of employment instead of excelling in productivity. Regardless what the goal setting, however, it can be ob-

served that the preoccupation with productivity (if defined as output/man) is an American sport, but not a European one. The Europeans view productivity and hence the capital/labor ratio in production as an interdisciplinary problem, where technology, economy, and social aspects intermingle.

It may be some food for thought to note that Europe, and especially Japan, protects its (by American standards) highly inefficient farming practices with high tariffs and import quotas. On the other hand, Japanese car-makers employ more robots for the export leaders than anybody else in the world—more because of the shortage of workers than because of cost (which may be well hidden in bank arrangements). This different view toward productivity will be noticed quite frequently by the American program manager in the NATO environment. He can, for example, expect (1) resistance to competitive bidding, and (2) the selection of contractors for socio-economic reasons. The European priorities in selecting weapon systems and contractors are about in this order: first, what is the socio-economic contribution; second, what is the cost of the system; and third, does it work? The American viewpoint exchanges the third with the first consideration; hence, conflicting situations are bound to develop, because no side can comprehend the other party fully.

SALES, ASSETS, AND NET INCOME

In order to illustrate any analysis on European taxation on profit, Tables II and III are provided; the first for European, the second for American defense-related companies. Both tables provide, for selected companies, the sales figures for 1977, with the assets and the net income for the same year. The term net income has been selected instead of profit in order to underscore the differences between fictitious and true profit as discussed earlier. In addition, in Columns 4 and 5 the sales/asset ratios and the percentage net income on sales and on assets are calculated. Also calculated are the European and the U.S. "averages," with the explicit warning that those averages, while they have demonstrative and indicative value, have no statistical value for the purist because of the sample size.

In order to facilitate the interpretation of Tables II and III, let's separate the results for the selected defense-related companies. Table IV shows that the European defense-related companies do approximately 25 percent less business (military and civilian together) than their American counterparts. Nevertheless, they own more than twice the assets of their counterparts in the United States. Or, differently expressed, for each dollar invested, American industry sells $2.50, and the European only 90 cents' worth of goods. In reverse, it takes $1.15 of investment in Europe for $1 of sales, while in the United States it takes only 40 cents to accomplish the same result, meaning that European industry is about three times as capital intensive than the American one. However, one has to be careful with such comparisons. It may say that European equipment is on the average

younger than the American (about 10 vs. 20 years), which does not necessarily mean it has to be better. In any case, I recommend some caution about making too rigid an interpretation although, and this is bad enough, the general trend cannot be disputed.

One may also note the low income figures in Europe compared to the United States: 1.7 percent vs. 3.6 percent on sales and 1.5 percent vs. 9.0 percent on

TABLE I
Import-Export as % of GNP

	100% GNP IN BILLION $	PERCENTAGE OF GNP	
		TOTAL EXPORT	TOTAL IMPORT
USA	100% = 2108	6.8%	8.7%
EEC	100% = 1950	23.7%	23.7%
USSR	100% = 1254	4.2%	4.1%
EAST EUROPE	100% = 384	16.7%	18.5%

TABLE II
Sales, Assets, Net Income-Europe
(Defense-Related Companies)
(1977 Figures)

NATION/COMPANY	SALES DOLLARS (MILLIONS)	ASSETS DOLLARS (MILLIONS)	NET INCOME DOLLARS (MILLIONS)	SALES ASSETS RATIO	NET INCOME AS A PERCENT OF SALES	NET INCOME AS A PERCENT OF ASSETS
WEST GERMANY						
SIEMENS	10.641	11.197	273	0.95	2.56	2.44
FRIED KRUPP *)	3.312	N A	N A			-
MESSERSCHMITT BOLKOW BLOHM	776	964	4	0.80	0.52	0.41
VFW FOKKER	716	787	(68)	0.92	(9.50)	(8.70)
STANDARD ELEKTRIK LORENZ	1.179	868	22	1.37	1.87	2.56
AVERAGE GERMANY	3.328	3.450	57.75	0.96	1.74	1.67
FRANCE						
SNECMA	684	1.260	19	0.54	2.78	1.51
THOMSON BRANDT	4.005	5.035	43	0.80	1.07	0.85
AVION M. DASSAULT BREQUET	1.159	2.405	42	0.48	3.62	1.75
AEROSPATIALE	1.933	3.270	(91)	0.60	(4.71)	(2.83)
AVERAGE FRANCE	1.945	2.980	3.25	0.65	0.17	0.11
UNITED KINGDOM						
HAWKER SIDDELEY GROUP	1.447	1.390	81	1.04	5.60	5.83
BRITISH AEROSPACE	1.500	1.055	51	1.42	3.40	4.83
ROLLS ROYCE	1.228	1.112	25	1.10	2.04	2.25
EMI	1.457	1.155	42	1.26	2.88	3.64
AVERAGE UNITED KINGDOM	1.408	1.178	49.80	1.20	3.54	4.23
AVERAGE EUROPE	2,227	2,536	36.92	0.88	1.66	1.46
AVERAGE IN ROUND FIGURES	2.200	2.500	37.00	0.9	1.70	1.50

*) EXCLUDED FROM AVERAGE

TABLE III
Sales, Assets, Net Income—United States (Defense-Related Companies) (1977 Figures)

NATION COMPANY	SALES DOLLARS (MILLIONS)	ASSETS DOLLARS (MILLIONS)	NET INCOME DOLLARS (MILLIONS)	SALES ASSETS RATIO	NET INCOME AS A PERCENT OF SALES	NET INCOME AS A PERCENT OF ASSETS
UNITED STATES						
BOEING COMPANY	4 018	[illegible]	[illegible]	[illegible]	4 48	10 16
GENERAL DYNAMICS	2 901	992	103	2 92	3 55	10 38
GRUMMAN CORPORATION	1 553	421	32	3 69	2 06	7 60
LOCKHEED	3 373	849	55	3 97	1 63	6 48
MARTIN MARIETTA	1 339	605	[illegible]	[illegible]	[illegible]	16 56
McDONNELL DOUGLAS	3 545	2 018	[illegible]	1 76	3 47	6 10
NORTHROP CORPORATION	1 60[illegible]	547	66	2 93	4 12	12 07
UNITED TECHNOLOGIES	5 551	2 136	96	2 60	[illegible]	9 16
RAYTHEON COMPANY	2 818	1 417	[illegible]	1 99	[illegible]	7 97
AVERAGE UNITED STATES	2 978	1 195	108	2 49	3 63	9 04
AVERAGE ROUND FIGURES	3 000	1 200	110	2 50	3 60	9 00

[illegible]

TABLE IV
Averages

	AVERAGE FOR USA	AVERAGE FOR EUROPE
1. SALES PER COMPANY IN $M	3,000	2,200
2. ASSETS PER COMPANY IN $M	1,200	2,500
3. NET INCOME PER COMPANY IN $M	110	37
4. SALES/ASSET RATION	2.5	0.9
5. NET INCOME AS PERCENT OF SALE	3.6	1.7
6. NET INCOME AS PERCENT OF ASSETS	9.0	1.5

NOTE: (SALES/ASSET) × (% INCOME ON SALE) = % INCOME ON ASSET

assets. However, this group of figures is not comparable. The American has to cover, from his profit, the inflation—or the difference between investment and replacement value—while for the European counterpart those differences are accounted in "cost." Therefore, a 9 percent profit on American assets combined with an 18 percent inflation rate is still a 9 percent *de facto* loss, while a 1.5 percent profit for the European is under all conditions true profit. On the other hand, a 9 percent profit (on paper) sounds good to the investor, while a 1.5 percent profit sounds quite poor to the American investor, but not necessarily so to the European investor in Europe. Besides, the methods of capital acquisition work differently in Europe than in the United States. The European investment market is bank-controlled rather than stock-controlled. Equity financing is rare in Europe; debt financing dominates. But, whatever it may be, the program manager has to live with it. Much more important to him should be the sales/asset ratio, because this is an indicator of the financial responsibility power of a company, defined as the degree to which the company can take the financial responsibility for the execution of an order at hand.

Let us clarify this statement with a simple example. Assume you want to build a custom-made house, and a large construction company, doing $10 million business a year, quotes you a price of $100,000. Your friendly neighborhood builder, on the other hand, with an annual business of $500,000 per year, offers you a price of $80,000. The large company may have $2 million in construction equipment, while your small builder owns only $10,000 of assets in the form of two old, 5-ton, delapidated trucks. Let us further assume that the large and the small company both have a good reputation. Which one will you select?

If you go with the large company, you settle from the beginning for $20,000 more; however, you may also settle for a 15 percent down payment when you initially order and the balance in cash upon delivery. You may never know how much the house has cost the builder; all mistakes in estimate and calculation go to his account, as does the profit, if he makes one. If you go with the small builder, you have some hope of saving $20,000; but right away he asks you for progress payments, because he cannot prefinance your house except perhaps with a bank. Fine, you agree, and after $80,000 is spent, you have a house without a roof. What now? You can sue him, and get two delapidated 5-ton trucks and an unfinished house, or you can pay whatever it takes to finish it. The difference is that when dealing with a large company "a contract is a contract," and you and the company are dealing at arms length. If the large company loses money, it can swallow it; if it makes money, it is not your business. However, with the small builder, the contract is a partnership agreement. He offers you his good will and his expertise and *you* take the risk, because he *cannot* take it, regardless of any good intentions he may have.

Now let's translate this to the European and the American defense-related industry. The European industry has the financial responsibility power because their assets are larger than the business volume. The American industry does not have the financial responsibility power because assets are much smaller than the business volume. The European can take the risk, but does not take it because he does not need government business and the company/government relationship develops into a planned partnership where the government takes the risk. The American *cannot* take the risk, but he must take it because he needs the government business, and the company/government relationship starts right from the beginning as an adversary one.

Epilogue

I started this paper with a "caveat," a warning to abstain from any value judgment in comparing Europe with the United States. This does not mean that Europe and the United States could not learn from one another's industrial practices, only that both parties must be fully aware that a direct and unmodified transfer of experiences is not possible, because the conditions—physical, mental, and emotional—are too different to permit the one to copy the other. But even beyond these cultural subtleties, comparisons on even trivial matters are often misleading. For example, even a simple price comparison on an item-by-item basis will not be informative; yes, most item-by-item prices in Europe are higher than in the United States; cars and apartments are smaller; the entire price structure is different, reflecting indigenous resource utilization, needed imports, and manufacturing and distribution techniques. On the other hand, in such a comparison, how do you place subsidized housing, free universities, and 6 weeks' vacation into your value system? Is it not simply a matter of personal and highly subjective preferences of what you like or dislike? And you cannot fight about tests. Hence, as suggested in the beginning, let's simply agree that Europe and the United States are different—and let the subject stand.

I would like to close with some bits and pieces that should give you, the program manager, something to think about whenever you enter the NATO arena:

—The home markets for most European manufacturers are too small to produce efficiently, making export to other markets a necessity. For American manufacturers, on the other hand, exporting may either be a burden, a convenience, or an advantage—but not a "must."

—Europe has had hundreds of years to learn to live without space, with few resources, and without population growth.

—Europe, after disastrous destructions in two world wars, has to a large degree given up any dogmatic ideology and *Weltanschauung*. Europe is peregrinating along purely pragmatic lines.

—Europe is, from a management point of view, not one system, but a conglomerate of many interacting systems of sovereign states. In order to understand what Europe is, think of the United States less the federal government plus more than 10 different languages and cultural variations.

—Europe has never had any antitrust laws. In contrast, (vertical) trusts have always been looked at as most efficient, and conglomerates of functional, unrelated companies barely exist. The European company will, as a rule, stay in its line of business and not enter unknown territory for "investment only." This concurs with the still-strong European opinion that if you run a chemical company, you should be a chemist first and a manager second.

—Europe prefers and supports the intensive mix and cooperation between industry and banking. The banks are considered as the finance side of the industry, and private dealing in stocks is practically unknown. The banks are mostly the proxy holders for the investors. This arrangement plays well together with the European profit definition—where companies need not have profit on paper in order to be considered wealthy. For example, a company can use for long-range planning large amounts for research, new equipment, expansion, promotion, accelerated loan repayments, etc., but might not show any "pay-out profit" for years. This also explains the extremely low profit figures for some of the wealthiest European companies. In Europe, the long-range profit is of more interest than the short-range profit.

—The law of most of the European nations is founded in Roman law and its child, the Napoleonic code. This influences the formulation of contracts and contract disputes—quite different in many aspects from the English practice.

With this I close the short course on awareness about two exciting worlds: here at home and overseas. Recognize and accept the differences and enjoy both worlds.

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Multiyear Procurement: A Current Perspective

Major Ronald H. Rasch, USAF
Major Jonathan L. Brearey, USAF

Because of continuing change and complexity in defense requirements, time and cost of defense systems acquisition have grown and subsequently influenced the authorization and appropriations proccess.

Appropriations for defense may be and frequently are combined. Prior to FY 1971 the Air Force Aircraft (3010), Missile (3020), and other Procurement (3080) appropriations were no-year appropriations and were available for obligation until expended. Since 1971, however, these appropriations have been designated multiyear and are now available for obligation for 3 years. Similarly, research, development, test, and evaluation appropriations were changed from no-year to multiple-year appropriations and available for obligation for 2 years. Appropriations may be severely restricted with respect to obligation—the legal requirement for disbursement of funds. The obligation is valid if the funds are available and the requirement is specific. Additionally, in the case of annual appropriations, ". . . the supplies or services contracted for must be intended to service a bona fide need of the current fiscal year."[1] Because multiyear procurement involves special provisions for the disposition of appropriations, a brief discussion of the meaning of funding concepts will be presented here.

Annual Funding

This is the current procedure for funding most programs. The authorizations and appropriations are granted by Congress one fiscal year at a time. The yearly budgets prepared by DOD reflect this policy by specifically requesting those funds intended for the upcoming fiscal year's programs. Annual funding should not be confused with 1-year, single-year, or annual appropriations, which restrict the executive branch from obligating the funds beyond the current fiscal year.

1. Department of the Air Force, *Fiscal Law*, AF Manual 110-4, Washington, D.C., 1 May 1974, p. 20-2.

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Annual funds may be designated as either 1-year, multiple-year, or no-year appropriations.

Full Funding

All funds required to cover the total estimated cost to deliver a given quantity of usable end items must be available at the time of contract award. This requirement has its basis in DOD Directive 7200.4 which states in part

> . . . the objective is to provide funds at the outset for the total estimated cost of a given item so that the Congress and the public can clearly see and have a complete knowledge of the full dimensions and cost when it is first presented for an appropriation. In practice, it means that each annual appropriation request must contain the funds estimated to be required to cover the total cost to be incurred in completing delivery of a given quantity of usable end items, such as aircraft, missiles, ships, vehicles, ammunition, and all other items of equipment. . . .

The policy applies to DOD programs covered within the procurement title of the yearly appropriations act, and affects only production, not RDT&E, contracts. An exception to the policy permits the procurement of long-lead-time components in advance of the year in which the associated end item is purchased. The full-funding policy prohibits any DOD agency from paying as costs are incurred for a production program that may span several years. This policy was adopted at the persuasion of Congress and the Office of Management and Budget (OMB) to preclude acquisition programs being started without sufficient funds available for completion, which would leave subsequent Congresses and administrations to either provide the necessary funding or terminate the program.

Multiyear Funding

Multiyear funding is the practice by which Congress authorizes and appropriates funds for progams in excess of 1 year. This term should not be confused with multiple-year appropriations, which specify the obligation time limits imposed on the executive branch. The importance of this term is that it refers to longer-term funds appropriated by Congress to fund program requirements for periods in excess of 1 year. Multiyear funding and multiyear contracting are not synonomous, although they may accompany each other.

Single-Year Procurement

Annual procurement, which results from annual funding is sometimes called single-year procurement and is "the way we are forced to do business

today. . . ."[2] No attempt to negotiate a contract in advance of the actual appropriations act is made because, by law, ". . . no officer or employee of the United States will make or authorize an expenditure from or create or authorize an obligation under any appropriation or fund in excess of the amount available therein. . . ."[3] Additionally, the full-funding policy prohibits contracting for more end items than can be purchased with available funds. The law and official policy, coupled with existing fiscal constraints and annual funding, effectively limit systems acquisition to annual procurement.

This situation exists because, over the years, members of Congress have had serious reservations about DOD using multiyear procurement to buy weapons. Their prime concern has been that Congress would be locked into either funding the procurements or appropriating funds to cover cancellation charges.

Multiyear Procurement

In the last few years a renewed effort has surfaced to provide for multiyear procurement for weapon system acquisition. The 1980 Defense Science Board advocated multiyear procurement to help solve several problems facing defense industry.[4] Witness after witness at the House of Representatives hearings on the capability of the U.S. defense industrial base stated that multiyear procurement concepts would significantly improve contractor capital investment, thus providing greater efficiency, lower cost, and shorter lead times. Because of these hearings, Representative Daniel has introduced a bill which would amend many of the restrictions currently limiting the use of multiyear procurement.[5]

CONCEPT

Multiyear procurement has become a generic term ". . . describing situations in which the government contracts, to some degree, for more than the current year requirement."[6] The defense acquisition regulation (DAR) defined multiyear contracting as ". . . a method of acquiring for DOD planned requirements for up to a 5-year period (4 years in the case of maintenance and operation of family

2. General Alton D. Slay, USAF, Commander, Air Force Systems Command, "The Air Force Systems Command Statement on Defense Industrial Base Issues," presented to the Industrial Preparedness Panel of the House Armed Services Committee, 96th Congress, 2d Session, 13 November 1980, p. vii-29.

3. *Fiscal Law*, pp. 1-7.

4. Defense Science Board, "1980 Summer Study, Task Force on Industrial Responsiveness, Summary Briefing," Washington, D.C., 15 August 1980.

5. U.S. Congress, House of Representatives, "Armed Services Procurement Policy Act of 1981 (H.R.745)," a bill introduced to the Committee on Armed Services, 97th Congress, 1st Session by Congressman Dan Daniel, 6 January 1981.

6. Deputy Secretary of Defense, *Policy Memorandum on Multi-Year Procurement*, Washington, D.C., 1 May 1981, Encl. - 1.

housing), without having total funds available at time of award." This point "without having total funds available at the time of award" is the key difference between multiyear funding and full funding. A multiyear contract under present regulations allows for the situation where only the first year of the contract is initially funded and ". . . the contractor is protected against loss resulting from cancellation by contract provisions allowing for reimbursement of unrecovered nonrecurring costs included in prices for cancelled items." The DAR continues by limiting the cancellation ceiling to $5 million unless increased by congressional approval. This restriction is the result of the Department of Defense Appropriation Authorization Act, 1976.

Current DOD fiscal policy does not allow for advanced buys of materials or items simply because they offer price breaks. "Items only qualify for advance procurement if they have significantly long production lead times."[7]

Additionally, the current DAR cancellation ceiling of $5 million only covers unrecovered *non*-recurring costs. Besides the standard DAR multiyear contract, there are other possible multiyear acquisition strategies designed to encourage competition, investment, and stability. These strategies are generally called expanded multiyear procurement and include varying degrees of advance funding and cancellation protection.

INDUSTRY VIEWPOINT

There is little doubt that industry views MYP positively. The Defense Science Board, in its 1980 Summer Study, expressed solid support for MYP.[8] The Board acknowledged the findings of the 1979 Defense Science Board Study on "Reducing the Unit Cost of Equipment," which recommended that DOD should seek multiyear appropriations (multiyear funding as discussed earlier) but concentrated on a different approach. This approach was directed at multiyear contracts using annual funds, because multiyear funding would ". . . exacerbate the current 'bow-wave' problem." The Defense Science Board stated that:

> The principal benefit of such longer-term contracting arrangements is to achieve economies of scale. With the greater assurance of a solid program, contractors have a much greater incentive to invest in productivity measures and to make economical buys from vendors and subcontractors. The savings potential for multi-year contracting is estimated to be from 10 to 15 percent (in constant dollars). This is based on recent studies, but it reflects the ex-

7. Slay, p. vii-30.
8. U.S. Congress, House of Representatives Subcommittee on the Department of Defense. *Department of Defense Appropriations for 1981*. Hearings Part 3, 96th Congress, 2d Session, 1980. Washington, D.C.: Government Printing Office, 1980, p. 1552.

> perience of the late 1960's and the early 1970's when multi-year contracting was used fairly extensively. An indirect benefit of the multi-year approach is that it provides a surge potential in the second year and beyond because the materials and suppliers are there if you have to surge.

Additionally, the Board found that the current limitations on the use of multiyear contracting require unacceptable risks to defense industry and, therefore, have resulted in only a few multiyear contracts. Specific recommendations were (1) revise DAR 1-322 to include recurring costs in termination liability provisions, (2) repeal the $5 million cancellation ceiling, and (3) revise DOD Directive 7200.4 to permit multiyear contracting without requiring full funding.

The Board's feelings on the subject of MYP are summed up well in a statement by Lockheed's Board Chairman, Robert A. Fuhrman, in which he cites single-year contracting as "the biggest problem we see in the defense business."[9]

Another defense industry group, the Electronic Industries Association (EIA), has gone on record as strongly supporting MYP. They note constraints of the present procurement system and advocate MYP as ". . . a stable base upon which to build." They note, also, that ". . . multi-year contracting has been constrained by the absense of a complimentary multi-year funding process."[10] The EIA's paper lists advantages, benefits, and risks associated with MYP. The advantages they list are it (1) encourages industry cost saving capital investments, (2) lowers material prices through larger quantity buys, (3) encourages maintenance of trained labor for government requirements, (4) allows better planning, (5) reduces administrative costs, and (6) increases price competition.

The EIA's position paper cites the lack of understanding on MYP advantages and, also, regulatory restrictions as reasons for reduced use of MYP in government contracts. The EIA advocated elimination of the current $5 million cancellation ceiling and establishment of a percentage of contract cost (20–30 percent) ceiling, which includes recurring costs such as material and labor. Other recommendations concerned longer than 1-year congressional funding, support of recent legislative proposals for MYP, and 100 percent progress payments for paid materials.

Other industry leaders have voiced similar support for the entire concept of MYP. Hughes Aircraft Company President, J. H. Richardson, in a letter to Rear Admiral N. P. Ferraro of the Naval Air Systems Command, encouraged the

9. "Aiming for Multi-Year Contracts," *Business Week*, 10 November 1980, pp. 46B-1, 46G-1.
10. Electronic Industries Association, Government Procurement Relations Council, "Multi-Year Contracting and Multi-Year Funding," position paper, Washington, D.C., 1980.

Navy to investigate multiyear contracting.[11] In this letter, Richardson stated that after 10 years of study on the subject of MYP, cost savings from 20 to 30 percent could be expected from a 3-year buy vs. annual procurement.

The Hughes Aircraft Company has been a leader in promoting enhancement of the multiyear concept. It has developed a complete package of legal issues and required legislative/regulatory changes. Their reasons for this effort are best summed up by their observations that

> . . . the impediments to multi-year contracting are associated with policy, perceived policy, directives or regulations, all of which may be changed with minimum effort, given the commitment to capitalize on the opportunities that longer term contracting would offer.

The Northrop Company is another example of industry interest in MYP. Their Chairman and Chief Executive Officer recently cited MYP as a key to production economies and industrial efficiency.[12] Northrop's faith in MYP led them to underwrite the risks involved in their multiyear contract for the B-52 AN/ALQ-155 power management system. Cost savings associated with the multiyear contract are documented at $10.6 million with savings being attributed to both economical purchases of material and efficient application of labor. Although the most efficient procurement would have been through an expanded multiyear contract with a higher-than $5 million cancellation ceiling and advanced buy of material, a standard DAR contract was eventually agreed upon because of potential violations of the full funding policy of DOD 7200.4. One of the Air Force's contracting officers involved in the contract negotiations concedes that only because of Northrop's desire for the multiyear contract did they accept the risks associated with the DAR cancellation limit and recurring costs restrictions, thus promoting the multiyear savings.

The Aerojet Corporation provides yet another example of both interest and participation in multiyear procurement. At a recent pricing symposium the company expressed the view that MYP can make a good acquisition program even better but cannot make a bad program good.[13] Additionally, the company spokesman warned that, if misapplied, MYP could make a good program bad. The Aerojet Corporation is presently participating (in competition with

11. J. H. Richardson, President, Hughes Aircraft Company, letter to Rear Admiral Neil P. Ferraro, USN, Assistant Commander for Contracts, Naval Air Systems Command, 31 March 1980.

12. Thomas V. Jones, Chairman and Chief Executive Officer of the Northrop Corporation, "Defense Acquisition Policy from an Industry Viewpoint," keynote address to the Fifth Annual Aeronautical Systems Division Pricing Symposium, Wright-Patterson AFB, Ohio, 6 May 1981, pp. 19-22.

13. Edward Elko, "Multi-Year Acquisition—Industry View," presentation by the Aerojet Corporation to the Fifth Annual Aeronautical Systems Division Pricing Symposium, Wright-Patterson AFB, Ohio, 5 May 1981.

Honeywell, Inc.) in a multiyear contract for the acquisition of 30mm ammunition for the GAU 8/A gun system, a subsystem of the A-10 aircraft. The contract is the standard DAR multiyear type for 3 years and offers $33.9 million in cost savings compared to three separate single-year contracts.

Because there are so many benefits for both sides, industry is overwhelmingly in favor of MYP. There are, however, some reservations. As indicated by the examples cited above, there are certain risks involved with a multiyear contract. Almost all advocates stipulate that their endorsement is based on increasing the cancellation ceilings and including recurring costs in the cancellation charge.[14] Witness after witness at the 1980 congressional hearings concerning the defense industrial base identified these two points as major requirements for advantageous use of MYP in major systems acquisition. Additionally, the witnesses recommended more flexible applications of the full funding policy. To guard against the risks associated with longer contract periods, industry leaders also advocate escalation clauses to protect contractors against the uncertainties in inflation, energy, and the cost of capital.

Because of the overwhelming support of industry and many government officials, the question has been raised as to why we do not utilize MYP more often. The answer has a complicated past because it deals with the views of Congress, DOD, and past administrations.

Congressional Viewpoint

The current emphasis regarding multiyear procurement is not the first attempt by DOD to utilize multiyear contracts. Multiyear contracts have been used since the early 1960s when the Department of the Army service-tested the concept in the procurement of small motors.[15] The thrust of current attempts to utilize MYP is for major systems that are now primarily single-year procurements. These single-year procurements are forced by congressional restriction. Earlier attempts to use multiyear concepts, however, were directed at the procurement of supplies and services which were funded with annual appropriations. The specific goals involved the issuance of multiyear contracts for supplies and services within the United States and overseas. The DOD felt that the annual contracts inhibited competition and drove up costs because many companies were unwilling or unable to take the risk of cancellation after 1 year, and those that did often under-

14. Lieutenant Colonel John W. Douglass, "Multi-Year Procurement—Making It Work for Systems Acquisition," draft, Cornell University Peace Studies Program, Ithaca, N.Y., undated, p. 15.
15. Lieutenant Colonel Jack P. Ancker and Captain Bruce S. Benefield, "Alternative Methods of Reducing the Ultimate Costs of the Government of Acquiring and Maintaining Items in the Inventory," unpublished master's thesis, SLSR-10-62/AFIT/LS, Wright-Patterson AFB, Ohio, June 1962, AD443005, p. 37; Logistics Management Institute, "Implementation Status—Multi-Year Procurement," Logistics Management Institute Report, unnumbered, Washington, D.C., February 1965, pp. 2-3.

bid their cost in the first year in hopes of recouping them through noncompetitive follow-on contracts.[16]

Presented to Congress to remedy these perceived problems was the Multi-Year Procurement Bill (HR 15789), which was subject to hearings held by the House and Senate Armed Services Committees on several dates in 1967 and 1968. At that time, weapon system procurement appropriations were no-year funds and MYP was being used for some weapon components. This practice was quickly questioned by Congressmen Gubser, Hardy, and Pike in the House, and Senator Dominick in the Senate. Their basic reservation involved DOD use of MYP for weapon systems and, as mentioned earlier, committing present and future congresses to either funding the procurements or funding the cancellation charge. The resulting legislation was Public Law 90-378, which allowed multiyear contracting with annual funds for *services outside* the contiguous 48 states and the District of Columbia. This less-than-optimal provision resulted from several legal readings from the General Accounting Office (GAO), which did not object to the proposed legislation but advised that operations and maintenance contracts executed and supported under authority of fiscal year appropriations could only be made within the period of their obligation availability. The GAO's basic concern was over the obligation of funds that were not available and subsequent violation of the Anti-deficiency Act. They felt that with sufficient wording, the multiyear contracts would remain legal. Additionally, Congress did not feel that budget authorizations should be tied up in order to cover the contingency of cancellation.[17]

During the late 1960s DOD had little trouble using MYP for acquisition. The appropriations for this purpose were no-year funds. There was little reason to challenge the cancellation record of government agencies, since few contracts were actually cancelled. Evidence to that effect was produced by a 1965 Logistics Management Institute study that reviewed all (42) multiyear contracts issued prior to 1965 and found that none had been cancelled.[18] The study also asserted that only 30 percent of the contracts that could potentially use multiyear procedures were actually issued as such but that administrative savings alone were in excess of $1.25 million.

Beginning with the early 1970s, MYP faced a dramatic slowdown. In 1972, the Navy presented Congress with two cancellation charges totaling over $388 million resulting from problems with shipbuilding contracts that happened to be

16. U.S. Congress, House of Representatives, "Multiyear Procurement Bill (H.R.15789)," Hearings of the Committee on Armed Services, 90th Congress, 1967-1968, No. 39-55, Washington, D.C.: Government Printing Office, 27 July 1968, pp. 7492-7500.
17. *Ibid.*, pp. 5726, 7529.
18. Logistics Management Institute, p. 29.

multiyear.[19] In response to this, Congress established a $5 million cancellation ceiling, which became law as part of the FY 1973 Armed Forces Authorization Act. This action was the legislators' way of maintaining control over multiyear contracting for weapon systems, and it has effectively eliminated major acquisitions from multiyear procurement. By imposing this restriction, Congress had hoped to prevent unfunded liabilities, such as the shipbuilding claims, from occuring after Congress had reviewed and approved the program.

At present, there is renewed interest in Congress concerning MYP. As mentioned earlier, a bill was introduced in January 1981 that would raise the cancellation ceiling and include both recurring and non-recurring costs. The bill was endorsed by the former Commander of the Air Force Systems Command, General Alton D. Slay,[20] and has general approval of many defense industry leaders.[21]

The most heated disputes over the issue have occurred within the House between the Armed Services Committee and the Government Operations Committee.[22] The Armed Services Committee supports the Daniel bill provisions,[23] but the Government Operations Committee has chosen to be more restrictive. The Government Operations Committee amendment retains the $5 million cancellation ceiling and would allow multiyear contracting on a larger scale only on a case-by-case basis. The Committee's reasons for this closely follow the historical stand Congress has maintained on the issue. The committee states "multi-year contracting fences in money, commits future Congresses to particular weapons systems acquisitions and reduces congressional oversight."[24]

One congressional aide voiced legislative skepticism by submitting that MYP would require a stable five-year defense program with realistic cost estimates and realistic inflation estimates and noting that he hasn't ". . . seen a stable five-year defense program in 14 years."[25] Another concern is that the increased multiyear authority granted by the Armed Services Committee would undo the work of the Office of Federal Procurement Policy (a branch of OMB), which is working to develop a uniform government-wide procurement policy.[26]

19. Douglass, pp. 2-21.

20. Paul S. Mann, "Defense Department to Continue 'Full Funding,' " *Aviation Week and Space Technology*, 15 June 1981, pp. 108, 113.

21. Roslyn M. Pieck, "Multi-Year Contracting: A Feasible Solution to the Erosion of the Defense Industrial Base and the Rising Costs of Major Systems Procurement?" Defense Systems Management College report, (draft), Fort Belvoir, Va., 1 April 1981, pp. 18-22.

22. "Multi-Year Contract Spurs Dispute Within Congress," *Aviation Week and Space Technology*, 29 June 1981, p. 26.

23. "MYP Cancellation Should Recognize Recurring Costs, House Panel Says," *Aerospace Daily*, 5 June 1981, pp. 198-199.

24. "Multi-Year Contract Spurs Dispute Within Congress," p. 26.

25. Mann, p. 113.

26. "House Unit Votes for Limited Multi-Year Procurement," *Aerospace Daily*, 11 June 1981, pp. 226-227; "House Panel Hits Pentagon Plans for Multi-Year Procurement," *Aerospace Daily*, 5 June 1981, pp. 197-198.

As the controversy continues in Congress, proponents of multiyear concepts are maintaining their stand that MYP is "the single most important change we can make to address defense industrial base problems. . . .[27] The Department of Defense and the General Accounting Office have consistently advocated the prudent use of the multiyear contracts.

Department of Defense Position

There is little evidence to indicate that DOD and the individual services have anything but consistently approved of multiyear procurement. From the Army's initial testing of the concept for supplies back in 1961 through the Navy's shipbuilding programs in the late 1960s and early 1970s to the current Air Force initiatives for major weapon systems acquisition, DOD has endorsed the concept and, as described earlier, appealed to Congress for more liberal laws and regulations.

The position of the Office of the Secretary of Defense (OSD) was best expressed by Dr. William J. Perry, former Under Secretary of Defense for Research and Engineering (USDR&E), in his statement to the House of Representatives Panel on the Defense Industrial Base. In his testimony Dr. Perry discussed longer-term commitment and funding as a key element in ". . . achieving enhanced productivity through multi-year contracting for an economic procurement quantity."[28] He described several multiyear alternatives but noted that the present multiyear option prescribed by regulation (DAR) is limited by the $5 million cancellation ceiling. Dr. Perry conceded the deletion of the ceiling would not solve all the problems involved and suggested that the full-funding policy, although still applicable to many programs, should be more flexible and allow advance funding of labor and material for programs considered stable. He pointed out that "few contractors would be willing to incur such investment expenditures without government commitment to fund and pay such costs as they occur. The cost of money is just too high to make this an enticing approach in a number of programs." Dr. Perry also expressed the view that no special statutory authority should be needed to enter into multiyear contracts, but that appropriate identification in the annual defense budget submissions to Congress would be sufficient. Incidently, the DOD is currently identifying all multiyear procurement programs with the designation (MYP). Interestingly, Dr. Perry also renewed the DOD's attempt to gain multiyear contracting authority for supplies and services funded with annual appropriations. Dr. Perry presented the following criteria for selection of multiyear programs:

27. Slay, p. vii-27
28. Congressional Hearings, p. 1402

—The configuration should be established;
—The inventory quantity should be known;
—The program should be non-controversial in need and mission; and
—The requirements should be included in the Five-Year Defense Program.

The current USDR&E, Dr. Richard D. DeLauer, has continued with the position Dr. Perry presented. He supports MYP because he feels it will encourage industry to make the necessary investments in equipment needed to improve productivity; however, he cautions that the multiyear approach cannot be applied to marginal programs that may change with a changing threat.[29]

The views of the Department of Defense have recently been officially pulished by Deputy Secretary of Defense Frank C. Carlucci in a "Policy Memorandum on Multi-year Procurement."[30] In this memorandum DOD remains committed to the full-funding policy, but allows for case-by-case consideration of programs. The memorandum presents the following criteria to aid in what it considers the "management judgment" involved in deciding whether to use or not to use MYP:
—Benefit to the government
—Stability of requirement
—Stability of funding
—Stable configuration
—Degree of cost confidence
—Degree of confidence in contractor capability.

It is apparent that the present administration is interested in using more multiyear concepts, but as Stephen A. Trodden, Deputy Secretary for Procurement in the Defense Comptroller's Office said recently ". . . how far and how fast we go is arguable. I do not think we should abandon the full funding principle all at once."[31]

With respect to the individual services, the Air Force and the Navy have advocated the expansion of MYP for weapons acquisition. General Slay, former Commander of the Air Force Systems Command, has been a leading advocate of MYP. His statement on the defense industrial base issues to the Industrial Preparedness Panel of the House Armed Services Committee included numerous advantages of multiyear contracting and presented several Air Force programs which have enjoyed significant savings owing to multiyear contracting. Additionally, General Slay proposed changes to existing law and regulations that have subsequently been included in the before-mentioned Daniel bill or addressed in the Department of Defense Policy Memorandum on Multi-year Procurement.

29. Alton K. Marsh, "Pentagon Begins Reforms of Acquisition Techniques," *Aviation Week and Space Technology*, Vol. 114, No. 22 (1 June 1981), p. 57.
30. Policy Memorandum on Multi-Year Procurement.
31. Mann, p. 108.

Another Air Force leader, General Bryce Poe II, former Commander, Air Force Logistics Command (AFLC), has also testified before the House Armed Services Committee Panel on the Defense Industrial Base in full support of MYP.[32] General Poe agreed with all the initiatives of General Slay and produced figures which further attested to the cost saving merits of MYP. Interestingly, but not surprising, General Poe returned to the subject of multiyear contracts with annual appropriations for supplies and services within the contiguous 48 states. Because the AFLC is responsible for logistics support of Air Force units and certain system acquisitions, the command feels it could benefit from MYP of supplies and services currently funded through single-year appropriations. Also in his statement, General Poe advanced an important multiyear concept he termed expenditure funding. This concept was developed to alleviate the cost-growth problems on the TR-1 aircraft program caused by production stretch-out decisions. Under this concept, which would violate the full funding policy, a quantity of items would be ordered and the contractor's costs would be funded on a yearly basis. No unfunded cancellation liability would result; however, delivery of end items may not be guaranteed until later years. General Poe contended that his command could save $95 million on the TR-1 through this multiyear procedure and allow for the purchase of 16 airframes instead of the 10 possible under the full-funding method.

One final comment concerning Air Force endorsement of MYP is in order. In interviews with several key managers of the Aeronautical Systems Division (ASD) at Wright-Patterson Air Force Base, the central theme was that MYP was not merely a contracting method but an acquisition strategy. Each officer acknowledged the advantages of a correctly applied multiyear procurement, but each one also considered full funding as "good business" procedure. The Aeronautical System's Division's Vice Commander, General Saxer, suggested that we may have gotten more for our money if we had fully funded each program one at a time at the most economically efficient rates of production. General Harbour, Deputy for Airlift and Trainer Systems, felt that full funding and annual funding were an "acid test" through which only good programs would pass. He also warned that inappropriate use of MYP could place future beneficial use of multiyear concepts in jeopardy.

The Navy has not taken a back seat in advocating MYP. Admiral A. J. Whittle, Jr., former Commander of the Naval Material Command, has also testified before the House Armed Services Committee Panel on the Defense Industrial Base. He endorsed the Defense Science Board's position on MYP and specifically recommended raising the cancellation ceiling. The Navy has employed multiyear contracts for several years and claims from 6 percent to 35

32. Congressional Hearings, pp. 911–924.

percent savings over single-year procurements on four example programs.[33] The Navy's record on the number of multiyear contracts placed additionally emphasizes their endorsement. From 1976 through the middle of 1980 the Navy placed 684 multiyear contracts as compared to 201 for the Army and 212 for the Air Force.[34] Conversely, the Army's value of first-years obligation under MYP contracts as a percent of total averaged 1.2 percent for the nearly 5-year period as compared to .53 percent for the Navy and .32 percent for the Air Force.

One last comment from the perspective of past experience is in order. In an analysis of factors associated with successful programs, a recent study questioned 110 individuals who had been in leading positions in Air Force acquisition since 1965.[35] A correlation of responses concering the importance of causes of success produced the following causes in order of importance:

—Strict adherence to system performance.
—Funding was consistent.
—The system was supported by HQ USAF.
—The requirement was responsive to the threat.
—The contractor demonstrated excellence.

The list of causes appears to agree with the criteria previously mentioned. Furthermore, the second most important cause, "funding was consistent," is a primary attribute of multiyear procurement. From this analysis, it does appear that MYP has excellent potential for making a good program better.

Government Accounting Office Position

Turning now to the position of the GAO on MYP, it is apparent that the Comptroller General has consistently advocated the cautious and prudent use of multiyear contracting methods. During the 1960s, as discussed earlier, the GAO testified in support of liberalized laws for DOD use of MYP. Since then the GAO has gone on record in several other instances in favor of expanded use of MYP. In 1978 the GAO, in a report to Congress entitled *Federal Agencies Should Be Given General Multi-Year Contracting Authority for Supplies and Services*, concluded that

> . . . the advantages of the multi-year procurement technique identified by agency officials outweigh the disadvantages and that the disadvantages can be minimized and control enhanced through

33. Captain J. S. Sansone and others, "Major Issues Challenge Effective Management of the Acquisition Process," *Naval Supply Corps Newsletter*, Vol. 43, No. 12 (December 1980), pp. 15-24.

34. Captain Cornell J. Hazelton, "Multi-Year Procurement—An Analysis of Its Established Criteria," unpublished research report, unnumbered, Army Logistics Management Center, Fort Lee, Va., November 1980, p. 18.

35. Frederick B. Wynn, *An Analysis of Success in Systems Program Management*, Advanced Technology, Inc., Report No. F33615-80-C-5184-II, Arlington, Va., 27 February 1981, pp. 7-9.

> adherence to appropriate criteria for use of multi-year procurement. We recommend that the Congress enact legislation authorizing multi-year procurement for Federal agencies. . . .[36]

This particular report specifically addressed the legislative restrictions on annual appropriations which preclude DOD's use of multiyear contracts for supplies and services within the 48 contiguous states. The report also identified several instances where significant cost savings were probable. Savings, exclusive of administrative cost savings, of 21 percent were identified.

In two other reports issued in 1979, the GAO continued its support of multiyear concepts. The first was issued in September and addressed to the Chairman of the Senate Budget Committee, Senator Edmund Muskie.[37] It was sent in response to a request by Senator Muskie for GAO help in determining the extent to which reform in procurement practices has been implemented by the DOD. The Comptroller General made several suggestions for improving major weapon systems procurement practices, one of which was to "make greater use of multiyear funding." The report cited annual funding as a contributor to uncertainty which inhibits contractors from making substantial capital investments that could keep costs down. Additionally, the report agreed with the many other authorities who saw several benefits to multiyear funding. These benefits are as follows:

—Greater stability;
—Improved production costs through greater contractor investment;
—Improved production costs through more favorable competitive negotiations; and
—Lower prices due to more economic purchases of material.

In the GAO's second 1979 report addressing the subject, entitled *Impediments to Reducing the Costs of Weapon Systems*, the agency tied MYP restrictions to congressional appropriations. Citing the period 1968–1973, when the DOD was able to use no-year funds for procurement, the report referred to savings in excess of $52 million resulting from the use of multiyear contracting. The emphasis regarding the issue appeared to be that multiyear contracting and asssociated savings could again be possible if the DOD were provided no-year or multiple-year authorization for procurement. As has been discussed earlier, DOD presently receives multiple-year appropriations for procurement, but because of annual funding, the full-funding policy, the $5 million cancellation ceiling, and realistic

36. Comptroller General of the United States, *Federal Agencies Should Be Given General Multiyear Contracting Authority for Supplies and Services*, Report to Congress (PSAD-78-54), Washington, D.C., 10 January 1978, p. 19.

37. Comptroller General of the United States, *Review of the Department of Defense's Implementation of Procurement Reforms*, Report to the Committee on the Budget, U.S. Senate (PSAD-79-106), Washington, D.C., 25 September 1979

budgetary constraints, DOD is effectively limited to a single-year procurement.

Most recently, in a report entitled *Multiyear Authorizations for Research and Development*, the GAO addresses some of the problems associated with the annual authorizations process.[38] The report specifically addresses several of the negative effects of the annual authorization process:

—The current annual process does not provide sufficient time to establish priorities.
—It inhibits long-range planning.
—Time constraints prevent large scale viewing of cross-agency programs.
—It adversely affects program stability.
—It makes important but long-term R&D efforts vulnerable to budget cuts and program interruptions.

Although addressing the peculiar problems of R&D the report confirms the many disadvantages of the annual authorizations and appropriations process. With this and previous reports, it appears that this cost-conscious agency joins the many other advocates of legislative and regulatory change toward expanded use of multiyear concepts.

Conclusion

The preceding discussion of the industry and government viewpoints toward MYP indicates that there are numerous issues to be resolved. There are advantages associated with MYP, but there are also risks involved. It is important to note that significant cost savings will involve risks. Additionally, the costs of flexibility is not light. The current legislative and departmental activity concerning the extent to which multiyear concepts are adopted is undoubtably a benefit/risk analysis which should ultimately provide for significant cost savings at acceptable risks.

As of this writing, the current restrictions of the defense acquisition regulation, annual funding, and the full-funding policy still apply. Exceptions are being considered on a case-by-case basis; however, in light of current initiatives, it appears that industry and government awareness of the need for expanded authority for multiyear procurement is driving toward a modernization of current DOD procurement strategies.

38. Comptroller General of the United States, *Multiyear Authorizations for Research and Development*, Washington, D.C., 3 June 1981, pp. 4-5.

Selecting Programs for Multiyear Procurement

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Lieutenant Colonel Kary R. Lafors, USAF

The Department of Defense and the services are developing guidance and implementing procedures for the expanded use of multiyear procurement (MYP) that has been authorized by Section 909, Department of Defense Authorization Act, 1982.[1] Additionally, the 1982 Appropriations Act and some DOD documents discuss what is needed prior to awarding an MYP contract. My intent in this article is to identify the essence of what is already required, and to provide some insight into what is expected to be in the forthcoming guidance. This article focuses on how to identify and evaluate candidate programs for multiyear procurement. Writing this article now, instead of after the new procedures have been published, is considered worthwhile because many program offices should be, or are, already reviewing their programs for possible use of multiyear procurement. First, I will describe the purpose of multiyear procurement, then review its characteristics.

The overriding objective of multiyear procurement is to obtain goods and services, including weapons systems, in the most efficient and cost-effective manner. Achieving these results can only be realized through the proper screening and selection of candidate programs.

Description

The most significant characteristic of a multiyear contract is that it is a method of acquiring more than 1 year, but not more than 5 years, of requirements under one contract. While one contract is written to cover up to 5 years of requirements, each program year is budgeted and funded annually. At the time of award, funds need to have been appropriated for the first year only.

Failure of the Congress to appropriate funding for future years is the only basis for cancelling the contract. Cancellation provisions are unique to MYP; they apply only in those cases where the government fails to fund future years. That does not affect the government's rights to terminate for convenience, however, if it is necessary or advantageous to do so. The right to terminate for convenience is the same for MYP as for other government contracts.

It is a mistake to equate an MYP to a single-year contract with options for following years. In the case of options, the government can choose not to exercise

1. U.S. Congress, House of Representatives. Section 909, Department of Defense Authorization Act, 1982 (HR 9786), 2 December 1981.

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the option for many reasons, and there is no obligation to pay the contractor for this decision. This limited commitment by the government keeps contractors from making commitments for those later-year buys, since they have no guaranteed protection in the event the government does not exercise the option.

Multiyear procurement is not total-package procurement. Total-package procurement included development and production phases, whereas MYP applies only to production.

The major benefit of MYP is reduced program costs. In addition, increased opportunity is provided for investment in productivity improvements. Savings can be achieved through any or all of the following:

—Increased competition at the prime-contractor level.

—Economic quantity buys of material throughout the subcontractor and supplier base.

—Improved competition at the subcontractor/supplier level of manufacturing materials and parts by the prime contractor.

—Improved labor and overhead efficiencies at the prime and subcontractor levels by optimizing costs for start-up and learning.

—Improved productivity in the manufacturing process as the result of increased corporate capital investments.

Strengthening of the industrial base can be achieved through the use of MYP contracts by allowing:

—Improved long-term productivity growth.

—Reduction of lead times for manufacturing materials and parts in the subcontractor/supplier base. This can occur by permitting the prime contractor to enter the subcontractor/supplier production queues only once at the beginning of the program, instead of re-entering the queues on an annual basis.

—Improved surge production capability for the overall weapon system, as well as for logistics sustainability, because of the bow wave of materials ordered at the beginning of the MYP contract.

Before discussing recent activity, it is worth noting that the definitions of many of the important and frequently troublesome terms used in conjunction with multiyear procurements are included in *Appendix A* at the end of this article.

Recent Congressional Activity

Section 909 of the Department of Defense Authorization Act, 1982, establishes statutory authority for MYP. The provisions provide that: (1) MYP may be used for major systems acquisition; (2) advance procurements may be made to obtain economic lot prices; (3) cancellation ceilings may include recurring and non-recurring costs; and (4) notification to Congress is required for ceilings over $100 million.

There are, however, also comments on MYP in the Department of Defense Appropriation Bill of 1982, and the accompanying report by the House Appropriation Committee. Unfortunately, there are differences in what these documents and a USDRE October 5, 1981, memo to the military services say about MYP.[2] The essence is that while the Authorization Act allows recurring costs in cancellation ceilings (advance buys) and implies cancellation ceilings need not be funded, the House Appropriation Committee and the Assistant Secretary of Defense (Comptroller) are requiring that advance buys for MYPs be funded to the termination liabilities.

Another way to view that is that since advance buys will be funded, there is no need to provide cancellation protection for those items. This means that cancellation ceilings can be used for non-recurring costs only. As a result, "up front" total obligation authority (TOA) will be required for MYPs to cover the costs of the advance buys.

The report also states that the House Appropriations Committee will require substantial supporting documentation to justify multiyear contracting for major programs. Specifically, the Committee will require documentation supporting benefits from MYP, stability of requirements, and funding profile; degree of cost confidence; and degree of contractor capability. The Committee will be looking for a full presentation of benefits "especially as they affect vendors, small suppliers, and subcontractors. . . . "[3]

This type of request for detail is a major factor in requiring a thorough explanation of the trade-offs for using MYP. More will be said later on the evaluation required for MYP. Next, let us consider what type program requirements might be possibilities for this technique.

Possible Candidate Programs

Multiyear procurement can be applied to a variety of programs. It can be used in the purchase of total or partial production requirements, applied in either competitive or sole-source acquisitions, or used to acquire a major system or a relatively minor component or share part. Modification programs can be purchased on an MYP.

The MYP can be beneficially applied to high- or low-dollar-value acquisitions and high- or low-rate production programs. In addition, it can be used in single-service or in joint-service acquisitions, in coproduction or foreign military sales

2. U.S. Congress, House of Representatives. Section 796, Department of Defense Appropriation Act, 1982 (HR 4995), 4 December 1981; U.S. Congress, House of Representatives. "Report on the Department Appropriation Bill, 1982." (Report No. 97-333) The Committee on Appropriations, 16 November 1981, pp. 185-192; "Funding for Multiyear Procurements," a memorandum for the Secretaries of the Military Departments from Under Secretary of Defense, Research and Engineering, 5 October 1981.

3. Report on the Appropriations Bill (No. 97-333), p. 191.

contracts, and in second-sourcing situations (the planning here is more involved, but the pay-off can be great). The important factor in selecting a program for MYP is how well it meets the criteria discussed below.

Criteria

Management judgment is required to decide whether or not multiyear procurement is appropriate and how it should be tailored. The DOD has prepared the following guidelines for decision-makers.[4] The criteria are to be considered in a comparative risk/benefit analysis. The items in paragraph 1 below represent the benefit factors, and the items in paragraphs 2 through 6 represent risk factors.

1. *Benefit to the Government.* Cost avoidance savings are probably the most significant benefit. They can be defined either in terms of absolute dollars or a percentage of total cost. Other benefits are improved delivery schedules and an enhanced defense industrial base. These should be quantified if possible.

2. *Stable Requirement.* There should be a low risk of contract cancellation. The need for the production item or service should remain unchanged or vary only slightly during the contemplated contract period. Production rate, fiscal-year phasing, and total quantities should be reasonably firm.

3. *Stable Funding.* There must be a reasonable expectation that the program will be funded at the required level throughout the contract period. Funding to cover the MYP must be identified in the five-year defense plan (FYDP) prior to award of the MYP.

4. *Stable Configuration.* The item should be technically mature with relatively few changes in design anticipated. Underlying technology should be stable. This does not mean that changes will not occur, but that the estimated costs of such changes are not expected to drive total costs beyond the proposed funding profile. Further, the changes would not allow the pricing integrity of the MYP to be lost. The increased costs of the changes should not significantly affect the projected savings due to MYP.

5. *Cost Confidence.* There should be a reasonable assurance that cost estimates for both contract and savings are realistic. Estimates should be based on prior cost performance history for the same or similar items, or on proven cost-estimating techniques. Cost confidence should be such that a firm-fixed-price or fixed-price-incentive contract is appropriate.

6. *Confidence in Contractor Capability.* There should be confidence that the potential contractor(s) can perform adequately. Potential contractors need not necessarily have produced the item previously. A formal evaluation of the poten-

4. "Policy Memorandum on Multiyear Procurement," a memorandum for Secretaries of the Military Departments, Directors, Defense Agencies; from Deputy Secretary of Defense, 1 May 1981, Enclosure 2.

tial value of multiyear should be accomplished whenever planned acquisitions meet the above criteria.

Funding

The services are required to fully fund the annual requirements. In addition, they will need obligation authority to cover the advance buys that are made for the MYP. Advance buys come under two categories—items bought to protect the schedule, and items bought in economic lot quantities to obtain savings. The method of funding these advance buys is to fund the contractor's termination liability for those items.

If the program office does not have all the necessary funding for the MYP advance buys, it may propose the MYP anyway. The Secretary of Defense has committed to providing funding to cover the shortfalls for economic buys of out-year components.[5]

Special Considerations

The complexity of the program will be a major factor in determining which years to start an MYP. If it is well within the state of technology, it might be acceptable to start with the first production run. A successful development program, followed by minimum or no major changes from RDT&E, could lead to a first-year production on an MYP basis. If the program were a parallel development in full-scale development, an MYP could be a natural follow-on. Factors such as the expected number of years of production would have to be taken into account as that might influence whether competition would be re-introduced in future production buys. If the program is a follow-on to competition, too complex to re-introduce competition, and will entail a lengthy production period (6 to 10 years), it is probably better to wait until the second or third production run to introduce an MYP. The design should be more stable by then, and cost history will be available.

If quantities are not stable in the early part of the planning process, but are expected to become sufficiently stable by contract award, planning for the MYP could be based on assumed quantities. This would allow comparison of single-year vs. multiyear costs and would acquaint the approval authority with the parameters of the MYP. Final selection of quantities could be included in the request for proposal (RFP), and, if necessary or advisable, option quantities could be used. The basic MYP would include the firm requirements. Options could be written for each year or for the end of the MYP.

5. USDRE memo, 5 October 1981, p. 1.

Because of the uncertainties that exist in longer-term contracting, special contract provisions are necessary to provide for proper sharing of risk. The uncertainties are treated with three general types of provisions: cancellation ceilings, special contract clauses, and unusual financing arrangements.

1. *Cancellation Ceilings.* The clauses in the defense acquisition regulation (DAR) need to be modified to reflect the allowance for the higher ceilings.

2. *Special Contract Clauses.* There are certain situations where risk is too difficult to forecast. In these cases it is advisable to provide for contingency clauses or contract re-opener clauses. Some areas for consideration in applying special clauses are identified below:

—*Exceptional Increases or Decreases of the Contractor's Business Base.* A special clause could apply to like-item sales only, or to the contractor's total business base.

—*Variations in Quantity.* In some cases the contractor may be able to accommodate small changes in the multiyear quantity, either on a year-to-year basis or on the total quantity.

—*Notification Clause.* It may be advisable to include a clause that would require the prime contractor to notify the government prior to making changes in his plans to buy advance materials.

—*Major Configuration Changes.* These should be priced in advance whenever possible.

—*Contractor Cost Performance Reporting.* Special tailoring of cost reports will probably be necessary for MYP. For some types of cost data it may be sufficient to have the contractor maintain the data and have it available for government review upon request. Cost data are useful in evaluating future contractor proposals, or in evaluating changes, should they occur.

—*Availability of Energy.* A special re-opener clause may be constructed if drastic changes in availability of energy to particular facilities are possible.

—*Foreign or Domestically Initiated Embargoes.* If unusual risk exists in cutbacks of critical materials, a re-opener clause may be appropriate.

3. *Unusual Contract Financing.* Early material buys may increase cost risk and could impact cash-flow. Various financing methods can be used to accommodate this risk. Each method must be considered in light of the total contracting approach. In some cases, a multiyear contract may not place unusual risk on the contractor, or such risk may be balanced with an equal opportunity for increased profits for superior cost management of the program. The descriptions below identify a set of circumstances that would increase the need to consider a particular type of financing. The type of financing may not be any different for MYP than that currently used on annual contracts.

—*Milestone Billings.* This method might be appropriate when there are high expenditures for initial investment items such as non-recurring tooling, test equip-

ment, or program facilities. It might also be appropriate when contractor deliveries do not occur until several months after the contract award. Consideration should be given to limiting milestone payments to four to six payments per year until deliveries start, and limiting payments to cumulative milestone values or actual costs, whichever is higher.

—*Unusual Progress Payments.* This method should be considered when extraordinary advance procurement of materials requiring high-dollar outlays are expected. In this situation, consideration may be given to use of variable progress payments. When considering unusual progress payments, a cash-flow analysis should be performed. The preferred analysis is through the use of the Department of Defense "CASH" cash-flow model. The analysis should provide assurance that the contractor is not being paid more than incurred costs. The analysis also should compare the level of financing under the increased payment rate to the level of financing that would occur without it.

—*Economic Price Adjustment (EPA).* This would probably be appropriate for all types of multiyear acquisitions. Economic Price Adjustment occurs when extraordinary economic conditions make agreed-to labor and material prices obsolete. The longer the life of the contract, the higher the probability of price obsolescence. Thus, EPA clauses can be critical to a multiyear acquisition.

—*Profit.* When unusual risks are not offset by unusual financing or other contract features, higher profits should be allowed. If appropriate, higher profits can be accommodated via the weighted guideline special factor allowances, Part IV of the DD 1547, or via a set premium profit allowance established for all multiyear acquisitions.

Evaluation

The program manager probably will be able to quickly determine if a program can meet the criteria for MYP. Once it is determined that MYP could be a viable approach, it will be necessary to perform an analysis to fully describe and quantify the proposed MYP. In a sole-source situation, the program manager can approach the contractor directly to help establish the nature of the savings and the risks involved. In a competitive environment, it will be necessary to rely on in-house estimates of savings and risks.

The primary source of savings on higher-rate production items is economic lot buys of material. The savings from these buys is dependent on the relationship between the prime and the subcontractor, the relationship between suppliers and their subcontractors, and so on down the line. The prime contractor should be able to perform quick analyses of savings and risks by having the material department contact the major subcontractors. A 30-day turnaround by the subcontractor would be reasonable in most cases. In a sole-source situation the PM can request this analysis directly. If it appears that MYP is practical, the program

manager can begin to lay out a timetable for completing a thorough analysis and obtaining required approvals.

Multiyear procurement enhances competition. More contractors should be interested in 3–5 years of requirements, rather than in requirements for only 1 year. However, in a competitive environment the government must treat all contractors fairly, not giving an advantage to any one. The result is that the government's contact with prospective offerors will be limited, and the program office will have to develop comparative single-year and multiyear estimates on its own.

The effort to document program stability and potential savings can be time-consuming and expensive. Its difficulty will be increased because the planning period is longer and the demand for detail is greater than for 1-year contracts. In some cases detailed planning for production will need to begin at the onset of full-scale development. See *Appendix B* to identify the time periods involved. It shows a 2-year planning cycle keyed to the programming and budgeting process. It is apparent that the requirement to evaluate programs for MYP as a part of the budget process poses one of the biggest challenges to the planning activity.

Types of Data Required

Savings. The progam office estimate of savings should be a mutual effort by the program office and the contractor for sole-source situations. For competitive buys the estimate will probably be an in-house estimate only. Later the estimates will be updated by contractors' proposals. Department of Defense policy requires that single-year proposals be requested, as well as MYP proposals. The nature of the savings should be identified in major categories and should include an illustrative example. The categories will probably be savings due to economic lot quantities of material, labor efficiencies, inflation avoidance, etc. These categories should be shown in constant dollars as well as then-year dollars. Short discussions of each category are also required. In some cases there may be different rates of production for the annual buys and the MYP. The savings accruing from any increased rate of production should be shown separately.

Stability of Funding. The funding requirements of single-year buys will be compared to both the current funding plan (FYDP) and the multiyear funding profiles. These will be shown by year. The funding requirements should be shown in both then-year and base-year dollars for both the single-year and MYP approaches. The program office will need to evaluate the risk of funding changes.

Cancellation Ceiling. The types of categories of items to be covered by the cancellation ceiling should be identified, and the dollar values of each category should be listed.

Advanced Buys. Separate breakouts of items bought for savings, and those bought for protection of schedule may be required. It is probably best to check

with your major command or service comptroller for the latest reading on this issue. A discussion of the basis for the savings for each category would be useful. Examples might include savings attributible to the following: minimum order quantities, economic production rates of subcontracted items, economic lot buys of raw materials by subcontractors, and economic production/assembly by the prime contractor.

Stability of Design. Identify the types of design changes that are expected to be implemented during the MYP. Include a short discussion of the extent of changes and their impact. Show the method of incorporating the changes into the contract, or if they are to be handled outside the MYP, summarize the arrangements. Prepricing of these changes is preferable when the nature of the changes is sufficiently well known.

Capital Investment. The program office should identify as early as possible the types of increased capital investment that the contractors are willing to undertake if they receive an MYP.

Impact on Competition. Competition might be reduced at the subcontractor level if an MYP is awarded in the early phase or middle of the production program. There is a chance that a supplier who is willing to seek subcontracts on a year-to-year basis may not be interested in bidding after a competitor has had 3 or more continuous years of uninterrupted production. The program office should identify these situations during the review process, and evaluate their impact on cost savings.

Risk/Benefit Analysis. Clearly document justification for using an MYP contract as part of the acquisition plan. Analyze costs, benefits, and risks for each alternative business strategy, e.g., annual buys vs. alternative MYP options. Based on the House Appropriations Committee draft report, it appears that a one-half- to one-page discussion will be required to provide the rationale for the level of risk assigned. Complete the analysis of each alternative business strategy as early as possible and include in the DOD planning, programming, and budgeting cycle. A present value analysis of the savings should be done in accordance with DODI 7041.3, "Economic Analysis and Program Evaluation for Resource Management."

Briefings. In addition to the Business Strategy Panel (BSP), separate briefings may be necessary to: gain approval for the secretarial determination and finding (D&F) for authority to negotiate; sustain the required funding levels for the MYP; or obtain the support of the headquarters approving authorities.

Alternative MYP Approaches. Program offices should be prepared to discuss alternative MYP approaches when requesting funding or approvals for MYP. Because the alternative MYP approaches can result in different annual funding profiles, alternatives may be useful for major command and service analysis and

program budget decisions.

The MYP approach will be approved based primarily on how well the program fits the criteria, the reasonableness of the savings, and the thoroughness of the evaluation. Outside influences on program stability are always a factor. Approvals are more likely if these factors are well understood and are controllable during the MYP period.

Including unusual arrangements with the MYP complicates the approval process, but should not be reason for disapproval. If unusual financing or other special contractual arrangements make sense, they should be included. If accelerating the delivery schedule for the MYP is reasonable, it should be done. The program office must be prepared, however, to spend the extra effort to explain the nature of the unusual conditions.

Approvals

When a secretarial D&F for authority to negotiate is required, it will have to be approved prior to release of a formal RFP for a multiyear procurement. An analysis of the potential savings from the MYP must be included in the request for D&F. For sole-source situations, authority to release a draft RFP prior to approval of a secretarial D&F may be requested.

If cancellation ceilings are expected to exceed $100 million, notification to Congress is required in accordance with Section 909 of the FY 82 Authorization Act. Cancellation ceilings less than $100 million will be considered to be initially approved upon approval of the POM by DOD. The services will be establishing approval levels to proceed with MYPs that require ceilings less than $100 million.

Appendix A

One of the biggest problems in discussing multiyear procurement has been the absence of universally accepted definitions. The list provided here includes the most commonly used terms and the most generally accepted definitions. They are grouped into two categories: acquisition terms, and financial terms.

Acquisition Terms

Multiyear contracting is a method of acquiring more than 1 but not more than 5 years of requirements under one contract. Each program year is budgeted and funded annually. At the time of award, funds need to have been appropriated for the first year only. The contractor is protected against loss resulting from cancellation by contract provisions that allow reimbursement of cost included in the cancellation ceiling. Multiyear contracting is not total-package procurement. Total-package procurement included development and production phases, where as MYP applies to production only.

Single-year contracting (annual buys) refers to the method of acquiring 1 or more year's requirements 1 year at a time (even though deliveries may extend over several years) through the use of separate contracts or through separately priced options on a single-year contract.

Cancellation is a term unique to multiyear contracts. A cancellation is the unilateral right of the government to discontinue contract performance for subsequent fiscal years' requirements. Cancellation is effective only upon the failure of the government to fund successive fiscal year requirements under the contract, or failure to put money on the contract by the time called for by the contract. It is not the same as termination. A termination would occur if current fiscal-year requirements were discontinued, or if a cancellation were effected despite funds being available. The contract cancellation clause must be included in all multiyear contracts.

Cancellation ceiling is the maximum amount that the government would pay the contractor for recurring and non-recurring cost (and a reasonable profit thereon) in the event of contract cancellation. The amount actually paid to the contractor upon settlement for unrecovered costs (which can only be equal to or less than the ceilings) is referred to as the cancellation charge.

Non-recurring costs, related to multiyear contracts, are production costs that are generally incurred on a one-time basis and amortized over the entire MYP production quantity. They include such start-up costs as plant or equipment relocation; plant rearrangement; special tooling and special test equipment; preproduction engineering; initial spoilage and rework; specialized work-force training; and unrealized labor learning, which is the unrecouped portion of a projected learning curve. Non-recurring costs may be included in cancellation ceilings.

Recurring costs, related to multiyear contracts, are production costs that vary with the quantity being produced, such as labor and materials.

Termination, contrasted with cancellation, can be effected at any time during the life of the contract. Cancellation is only affected if funding for the second or later years of the MYP is not received. Termination can be for the total quantity, or a partial quantity, whereas cancellation would be for all subsequent fiscal years' quantities. A termination can apply to any government contact, including a multiyear contract.

Termination liability is the maximum cost the government would incur if a contract were terminated. In the case of a multiyear contract terminated before completion of the current fiscal year's deliveries, termination liability would include an amount for both current-year termination charges and out-year charges.

Advance buy procurement is exception to the full funding policy. An advance buy, or advance procurement, is the acquisition and financing of components, both recurring and non-recurring, in a fiscal year in advance of that in which the

related end item is to be acquired. Advance-buy financing may be used to cover the costs of materials, parts, and components for subsequent years as well as costs associated with the further processing of those materials, parts, and components.

There are two categories of advance buys The first includes the traditional type of item that is bought early to protect an overall delivery schedule. The second type includes items bought in advance simply to obtain savings. It is worth noting that the definitions are not mutually exclusive. An item could be purchased to protect schedules, and at the same time be bought in economic lot quantities that include 4 years' worth of requirements in order to save money. Advance buys can be part of a multiyear contract or a single-year contract.

Block buy is a method of acquiring more than 1 year's requirement under a single contract. A total quantity is authorized and contracted for the first contract year. A block buy is a type of MYP and is funded to the termination liability.

Financial Terms

Multiyear funding involves a congressional appropriation covering more than 1 fiscal year. Congress is not now appropriating funds more than 1 year at a time. That is, they do not appropriate FY 83 funds in FY 82. Multiyear funding is not synonymous with multiyear contracting. The terms should not be confused with 2-year or 3-year funds (called multiyear appropriations), which cover only 1 fiscal year's requirement but permit the executive branch more than 1 year to obligate the funds.

Full funding is the congressional obligation authority (OA) for fully financing any quantity of end items in a single fiscal year. It is implemented by DODD 7200.4. Currently DODD authorizes an exception to full funding—advance buys to protect schedule. An additional exception is expected to authorize advance buys to obtain savings. Under full funding, funds are to be available at the time of contract award to cover the total estimated cost to deliver a given quantity of items or services. The entire funding needs of the fiscal year production requirements are provided unless an exception for advance procurement is used. A test of full funding is to ask the question, "Does any part of this year's buy depend on a future year appropriation to obtain delivery of complete units?" If the answer is yes, the contract is probably not full funded. The principle of full funding applies only to the procurement title of the annual appropriation act and therefore affects production contracts but not RDT&E contracts.

Termination liability funding refers to the method of obligating sufficient contract funds to cover the contractor's expenditures plus maximum termination liability, but not the total cost of the completed end items. Funds are designated for specific increments of work to be accomplished during the fiscal year for which the funds are approved. Increments of work are based on ecomonic pro-

duction considerations of the total end items on contract but are generally not segregated to a specific subset of the total quantity. This concept has only limited applications to production type programs and should be considered as an exception to normal procurement financing. Funds are not available at the time of contract award to complete and deliver a quantity of end items in a finished, military, useable form. Funding to termination liability is commonly done in RDT&E programs. There are two types of costs covered by this method of funding. The first is the contractor's expenditure and the second is the not-to-exceed amount of termination costs that could be incurred if the contract were terminated. In the event that a contract were terminated, the total cost liability would be covered.

Under *incremental funding*, funds are appropriated, obligated, or committed in a piecemeal manner rather than all at once. This term is commonly used to mean "funding to termination liability" when used in conjunction with RDT&E funds.

Expenditure funding involves funding to the contractor's expenditures. The termination costs are not included or funded using this approach. If a contract were terminated, additional funds would be necessary to cover the termination costs.

In an *incrementally funded block buy* production program for the MYP is *authorized in the first year*. Funding is provided annually at the termination liability level.

Appendix B

Key Milestone Events

The events and timeframes shown below are suggestive of the timing that goes into planning and executing a multiyear procurement. Many other scenarios are possible. The one shown might be considered "normal" processing. It is to be hoped, however, that MYP would be considered earlier in the development of the acquisition strategy. If the program were of sufficient priority, and stability could be expected in production, MYP could be indicated as a preferred strategy early in the demonstration/validation phase.

The schedule below is tied to the PPBS cycle. Processing requests outside the PPBS cycle is possible but is expected to be much more difficult. Getting an agreement to support stable requirements and funding for the MYP periods is probably much easier during the normal PPBS cycle. This is particularly true of larger programs with cancellation ceilings over $100 million.

The schedule shown allows 24 months from the initial decision to pursue MYP until contract award. This period is considered realistic: allowing more time would be beneficial.

Because of the extensive nature of the planning and proposal efforts, direct funding of the contractor's proposal is recommended wherever possible. Consequently, if MYP is considered reasonably likely, funds should be identified in the FSD phase and a line item included in the FSD contract for an MYP proposal, evaluation or trade-off study.

Event

	Suggested Completion
1. Program Manager's Initial Assessment	Jun CY 1
2. Contractor's Initial Assessment (for sole source selection)	Jul
3. Government's Initial Assessment (for competitive situation)	Jul
4. Planning the Task of Obtaining the Supporting Rationale for MYP	Aug
5. Completion of a Study of MYP	Dec
6. Analysis of the Study by the Intermediate Level Staff	Jan CY 2
7. Identification of Candidacy in the PPBS (POM)	Jan
8. Analysis by Head of Contracting Activity	Feb
9. Analysis by Service Headquarters	May
10. Analysis by Service Secretary	Jun
11. Analysis by ASD(C), USDRE(AP)	Aug
12. Identification of MYP in FYDP*	Aug
13. Release of RFPs	Sep
14. Receipt of Proposals	Dec
15. Quick Evaluation of MYP	Jan CY 3
16. Briefing to Head of Contracting Activity	Apr
17. Negotiations	Apr
18. Contract Award	Jun

*Identifying MYP as the method of procurement in the DOD approval FYDP would constitute approval for MYP unless the program required a cancellation ceiling of more than $100 million or it were a major program. Congressional notification is required if ceilings are over $100 million or if the program manager is a major (DSARC) program.

Evaluation of Laboratories

68

Colonel G. Dana Brabson, USAF

As we board a modern-day jetliner and glance into the flight deck, we are struck by the awesome number of dials and indicators and by the seemingly endless rows of knobs and switches. It is difficult to realize that the age of powered flight began only 79 years ago. Even so, the days have long since vanished when the pilot could fly his plane by putting one hand on the stick and the other on the throttle, and only occasionally glancing at his compass and his altimeter—if he had one. Long gone are the days when the pilot flew "by the seat of his pants." In many respects, it would not be far wide of the mark to acknowledge that today's pilots are managers rather than technicians. The pilot's job is to gather data, make decisions, and manage the flight systems that control his aircraft.

Today's research and development laboratories share many characteristics in common with today's jet aircraft. The laboratories, like aircraft, have developed at an unprecedented pace over the past few decades. Today's laboratory may have several hundred definable work units,[1] each of which is quite complex. Gone are the days when the laboratory director placed his mark on each work unit and actively participated in the development and implementation of each new idea.

And yet, in spite of the rapid development of technology, it appears that techniques for assessing the effectiveness of a laboratory are neither well developed nor widely used. It is true that dozens of studies have been conducted and hundreds of papers have been written;[2] nevertheless, the activity persists, and

1. A work unit is the smallest definable package of work to which resources are assigned and for which milestones are established. In the broader context, several work units constitute a task, and several tasks make up a project.

2. The Hughes Aircraft Company has been deeply engaged in an analysis of its own operations for many years. The generically applicable results of this analysis can be found in the following reference: "R&D Productivity, An Investigation of Ways to Evaluate and Improve Productivity in Technology-Based Organizations, Study Report," Second Edition, Hughes Aircraft Company, Culver City, Calif., (1978). This report provides many useful insights and has a 68-page bibliography listing over 1,000 references.

Author's note: I am deeply indebted to the following "managers and anti-managers," who, as a group, formulated many of the ideas presented in this paper and patiently reviewed the contents: Dr. A. H. Guenther, E. G. Clements, Lieutenant Colonel L. O. Hoeft, Lieutenant Colonel L. L. Tew, and Major C. F. Dean, all from the Air Force Weapons Laboratory.

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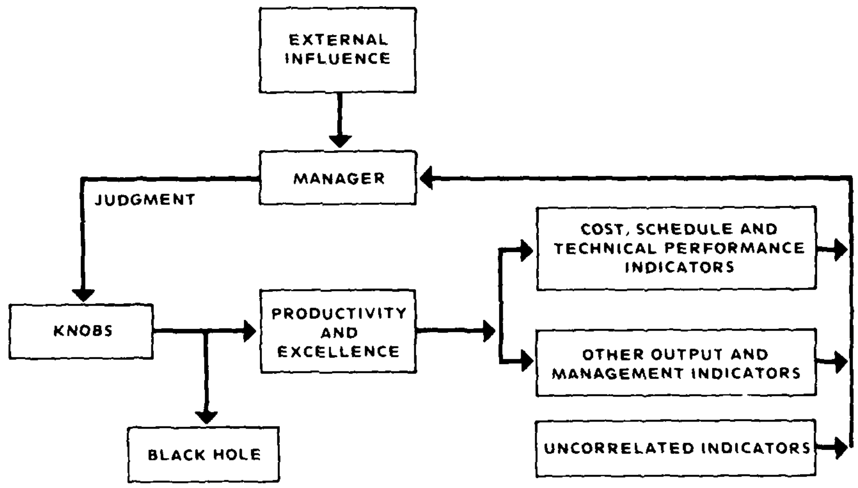
FIGURE 1
Relationships in the R&D Laboratory



management continues to ask how it might evaluate its laboratories more effectively.

The stress on evaluating the research and development laboratory is a relatively recent phenomenon. The private sector and the government are applying great pressures to ensure they receive maximum return for the resources invested in research and development.

A Model

At the outset, it is useful to present a very simple model of the dynamic relationships that exist in a typical research and development laboratory (Figure 1). Although most of the relationships are self-evident, a few comments are in order.

Knobs: A knob may be viewed as a control that the laboratory director has both the ability and the authority to manipulate. Perhaps the most obvious knob is the distribution of resources (personnel, dollars, and facilities).

Productivity and Excellence: Productivity and excellence are two characteristics of a laboratory that its director seeks to maximize. Unfortunately there rarely is a single-valued relationship between knobs on the one hand and productivity and excellence on the other; while advancement of a knob may, up to a point, increase productivity and/or excellence, further advancement usually results in a reversal of the trend and decreased effectiveness.

Black Hole: There are some knobs that appear to have no discernable relationship to productivity and excellence; on one day, operation of a particular knob will increase effectiveness while, on another day, the same operation will have the opposite effect. These knobs may be considered to be operating on a black hole.[3]

Indicators of Productivity and Excellence: Some elements of the productivity and excellence of a laboratory are amenable to quantitative measurement, while others can be assessed only qualitatively. The Hughes Aircraft Company study correctly points out that, as the degree of abstractness of the work increases, the work becomes more amenable to qualitative assessment and less suitable for quantitative measurement. This relationship is illustrated by Figure 2, constructed after that in the Hughes Aircraft Company study.[4] Needless to say, the highest degree of abstractness and creativity is found in the basic research work units. As one progresses to engineering development, the work becomes better defined and càn be evaluated more readily by quantitative techniques. It also is useful to note that quantitative measurements of performance can be evaluated by project officers at the lowest levels of management; however, it takes experienced managers, far up in the management structure to accurately assess the effectiveness of very abstract and creative efforts.

Uncorrelated Indicators: Just as there are some knobs that bear no apparent relationship to effectiveness, there are also some indicators whose values are apparently unrelated to the productivity and excellence of the laboratory. This fact presents the manager with an interesting problem: He must somehow decide which indicators are true measures of productivity and excellence and which are not, and then he must resist the temptation to operate the knobs that influence only the irrelevant indicators.

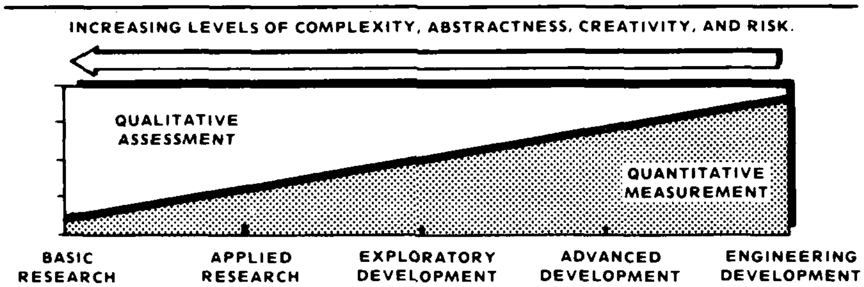
Manager: The key to the model is, of course, the manager. He must read the indicators, apply his judgment, and operate the knobs. It seems unlikely that the day is near when the manager can be replaced by a forcing function that automatically senses the positions of the indicators, consults the algorithm of the model, and drives the knobs to new settings.

External Influence: We do not need to elaborate on the impact of externally imposed organizational, governmental, environmental, and sociological influences; these influences establish the boundary values within which the laboratory operates.

3. A black hole is a location in which the gravitational field is so intense that not even photons can escape. Since no observables (e.g., photons) can escape, the location appears "black" to the outside observer.

4. R&D Productivity, Hughes Aircraft Company (1978), p. 39.

FIGURE 2
Spectrum of R&D Activities



Why Evaluate?

An evaluation of the productivity and excellence of a laboratory serves two vital functions: (1) It indicates to the manager the state of the laboratory; and (2) it tells the manager how the laboratory responded to his management initiatives. It is, of course, necessary at the outset to establish a baseline and then to periodically check for deviations from this baseline. An apparently spontaneous deviation from a desired baseline can indicate that a corrective management initiative is required. Moreover, following implementation of an initiative, the periodic evaluation will show whether the desired effect was achieved.

Outputs—A Poor Measure

Perhaps the simplest model of an organization pictures it as a black box that receives inputs and produces outputs; the box has a variety of knobs, some of which are manipulated internally and some of which are operated externally. Some of the outputs of a research and development laboratory are visible and countable; chief among these are hardware, reports, and oral presentations. Because these products are so easily counted, it is tempting to do so and to assign a figure of merit that is proportional to the total number of denumerable products produced by the laboratory. In the final analysis, however, outputs are poor measures of the productivity and excellence of the laboratory. Some of the reasons leading to this conclusion are worth stating.

First, outputs are easily manipulated. Consider, for example, articles in refereed technical journals. If a scientist is told that he will be rated on the number of papers he publishes within the next year, he may elect to divide one long paper into several shorter ones, and to publish the same basic information (with small variances) in two or more journals. In short, organizations are remarkably clever; given such a quantitative goal, an organization will almost always meet or exceed that goal.

Second, the simple counting of outputs fails to recognize that individual outputs differ widely in intrinsic value. The sum on many mediocre achievements rarely equals the value of one key scientific advancement such as the invention of the laser.

Third, given a quota of outputs, an organization may devote so many resources to the achievement of this near-term goal that the long-term health of the organization is jeopardized. Even the process of reporting, as necessary as it is, can be carried to an unhealthy extreme. There is a great deal of truth in following tongue-in-cheek observation. "The more time you spend in reporting what you are doing, the less time you have to do anything. Stability is achieved when you spend all your time doing nothing but reporting on nothing you are doing."[5]

Criteria

Before developing a methodology for evaluating laboratories, it is well to state a set of elementary criteria—a framework within which to construct the methodology.

First, the method must be cost effective; the expected benefits must warrant the required expenditures of resources. This criterion dictates that the methodology be reasonably simple and easy to apply. One must remember that resources—primarily personnel—will be consumed by any laboratory evaluation scheme. If these same resources were dedicated to direct research, an increase in productivity would result, an increase that might exceed the increase to be expected from improving the management of the laboratory.

Second, the methodology must be capable of treating both quantitative and qualitative data. For our purposes we shall insist further that the methodology be capable of combining quantitative measures with qualitative assessments to arrive at a *quantitative* measure of the effectiveness of the laboratory.

Third, the methodology must be consistent with good management practice.

Fourth, the methodology should capitalize on existing management structures and methods. More specifically, the methodology should take advantage of existing planning, review, and assessment mechanisms.

The Award Fee Contract

Of the many types of contracts awarded by the federal government, the award-fee contract is probably the most flexible. Like some other types of contracts (cost-plus-incentive-fee, for example), the magnitude of the fee awarded to the contractor is proportional to the performance of the contractor. The award-fee contract is unique in that the fee is proportional both to quantitative *and* to

5. Cohn's Law, which is attributed, perhaps apocryphally, to the Israeli Air Force.

qualitative measures of performance. The heart of the award-fee contract is criteria against which the performance of the contractor is judged. The contract identifies both the countable products that the contractor is expected to produce and the qualitative standards of performance the contractor agrees to maintain. The contract further establishes the relative importance assigned to each criterion and identifies a method by which numerical values are to be assigned to all (both quantitative and qualitative) measures of performance. At the end of each award-fee period, a single figure of merit is computed for the performance during that period, and the fee to be awarded is computed from the figure of merit by a predetermined formula.

Application

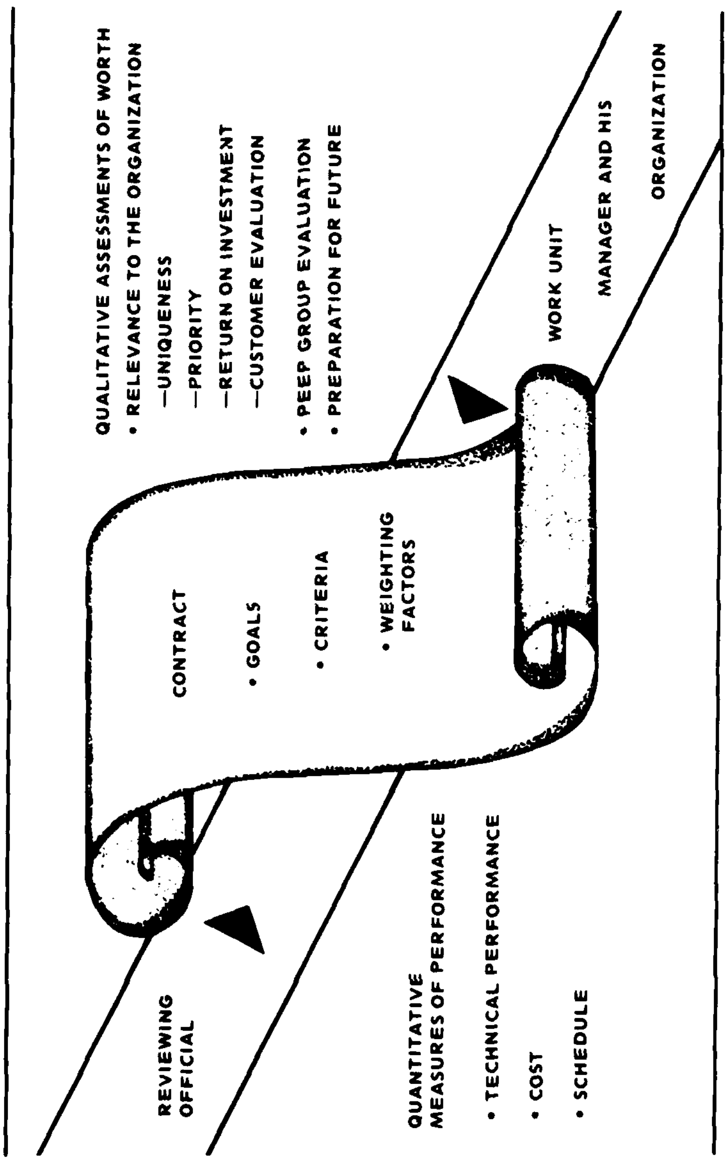
It is the ability of the award-fee contract methodology to treat quantitative and qualitative factors that makes this methodology attractive as a technique for evaluating the effectiveness of a laboratory. As a point of departure, let us consider the relatively straightforward application of the award-fee methodology to the application of a single work unit. In later paragraphs we will address the more complex problem of evaluating a laboratory in which many work units are in progress.

Application to a Work Unit

The evaluation of an individual work unit is illustrated conceptually by Figure 3. The evaluation combines quantitative measurements of performance with qualitative estimates of the worth of the work. Two of the most common quantitative measures of performance are schedule performance and cost performance. The schedule and cost performance are simple ratios that compare the targeted schedule and cost with actual schedule and cost. Needless to say, the determination of these indicators is predicted on the existence of a "road map" that identifies key work-unit milestones and projected costs; such a road map is a key element of the contract between the reviewing official (who monitors the work unit) and the work unit manager (who directs the work unit).

At this juncture, the manager of a basic research work unit complains bitterly: "Ridiculous! I cannot legislate that my basic research program will yield a new invention by the first of August! It is patently absurd to identify milestones for a basic research work unit!" The work-unit manager has hit on a key issue. It is crucially important to identify milestones; but not just *any* milestone will do. It is unreasonable to expect that the research group will invent four new blivots each year, one each quarter. But it is entirely reasonable to expect the group to complete, by a preselected date, a set of experiments that challenge the validity of a certain scientific hypothesis, thereby laying the groundwork for further work and, perhaps, yielding a new blivot. The manager must contract to achieve a set of clearly defined milestones that should be achievable within the allocated resources.

FIGURE 3
Measurement of Productivity and Excellence



Having dealt with some measures of performance that can be quantitatively determined, let us now turn to additional measures that can be assessed only in qualitative terms. As noted in Figure 3, these measures deal with the worth of the work. Although many different factors could be assessed, only three which appear to be of overriding importance have been selected.

Relevance: How important is the work to the mission of the organization?

Peer-Group Evaluation: What is the quality of the science and technology in the view of impartial external observers?

Preparation of the Future: Are adequate resources being devoted to development of the technology base?

By means of a behaviorally anchored rating scale such as that shown in Figure 4, numerical ratings can be assigned to the qualitative assessments of these three factors. Note that this is precisely the technique used in developing a performance index for an award-fee contract.

The final step is to combine the quantitative measures of performance with the qualitative assessments of worth, thus arriving at a single index for the work unit. Because it is unlikely that all factors will be considered to be equally important, a weighting factor (established in the contract between the reviewing official and the work-unit manager) is used to give the appropriate emphasis to each measure of performance and worth.

Application to a Laboratory

Application of the award-fee methodology to the evaluation of an entire laboratory poses a unique challenge. On the one hand, the laboratory director could simply accumulate and combine data from all his individual work units; perhaps he could give each work unit a relative weight proportional to the resources devoted to it. On the other hand, it is clear that laboratories have their own milestones, many of which are aggregates of the milestones of the individual work units. In addition, criteria can be defined against which to qualitatively assess the worth of the laboratory. In my judgment, each of these schemes has merit and complements the other. It is therefore suggested that the laboratory director use elements of both schemes to obtain an overall evaluation of his organization.

Needless to say, the director of a laboratory does not operate in a vacuum; he reports to a boss in exactly the same manner that the manager of an individual work unit reports to *his* boss. In the case of an industrial organization, the laboratory director may report to the vice president for research. In the Air Force, the laboratory directors report to the Director of Science and Technology, Headquarters, Air Force Systems Command. There is a real (although often unwritten) contract that identifies the laboratory's milestones and standards of performance. To be effective, this contract must be perceived as a firm commitment by the laboratory to achieve the laboratory's milestones *by* the agreed-upon

FIGURE 4
Behaviorally Anchored Rating Scale for Measurement of Worth

	RATING				
CATEGORY • CRITERION	POOR (0-44)	MARGINAL (45-66)	GOOD (67-80)	EXCELLENT (81-91)	SUPERIOR (92-100)
RELEVANCE • UNIQUENESS	Similar efforts widely distributed in private sector	Similar efforts scattered among a few organizations in private sector	Work in federal government only; no interest and/or capability in private sector	Problem unique to DOD; AF has major interest and commitment to its solution	Problem unique to AF; only AF is working on it
• PRIORITY	Work is unrelated to any other AF program	Peripherally related to another AF program	Bears direct relationship to other AF programs but is not pacing	On critical path of major AF program	On critical path to development of new war-fighting capability
• PAY-OFF/ROI	No foreseeable pay-off for AF systems	Could have minor effect on efficiency or nature of AF operations	Could have significant effect on efficiency and/or nature of AF operations	Could change way AF conducts its battles and/or operations	Could change way AF would fight a war
• CUSTOMER EVALUATION	Unrelated to any present or perceived future work by customer	Possibly of interest to customer at some future point in time	Weakly coupled to customer's efforts	Strongly coupled to customer's efforts	Directly coupled to customer's major efforts
PEER GROUP EVALUATION	Poor imitation of work which is being pursued elsewhere with much better effect	Quality of work is equivalent to that being done elsewhere	Work is better than that of all but a very few organizations	State-of-the art work of excellent quality	Explores the frontiers of science and/or technology
PREPARATION FOR FUTURE	Sacrificing technology base in order to meet immediate goals	Pursuing immediate goals with no concern for furthering technology base	Limited efforts to expand technology base in scattered parts of program	Major efforts to expand technology base at many critical places in program	Pursuing major new technology or scientific discipline

dates, and *with* the agreed-upon resources. Under these circumstances, the contract can be the basis both for a critical self evaluation of the laboratory by its director, and for an assessment of the health of laboratory by the boss to whom the laboratory director reports. *The award-fee methodology provides a uniquely* suited technique for accomplishing this evaluation and assessment; and the award-fee methodology can be applied to the laboratory in *precisely* the same *manner that it is applied* to an individual work unit. Critical to this process is the identification of suitable laboratory milestones.

Of course, the laboratory director has more available data to him than he can use effectively. In particular, he has the individual evaluation for each work unit. Because there may be several hundred work units in a laboratory, it is clear that a technique is needed that condenses the available data into a usable package. One solution is to compute the numerical average of the indexes for the individual work units. Unfortunately, the single number thus calculated has little information content. A more effective technique is to prepare a histogram that displays the number of work units as a function of performance index. (See Figure 5). *With this display, the laboratory director can decide what work units need his* personal attention.

At this point, it is appropriate to ask: How often should this evaluation process be exercised? In my judgment, once a month. This frequency seems to strike the proper balance between the resources expended in preparation of the review and the benefits to be expected from the review.

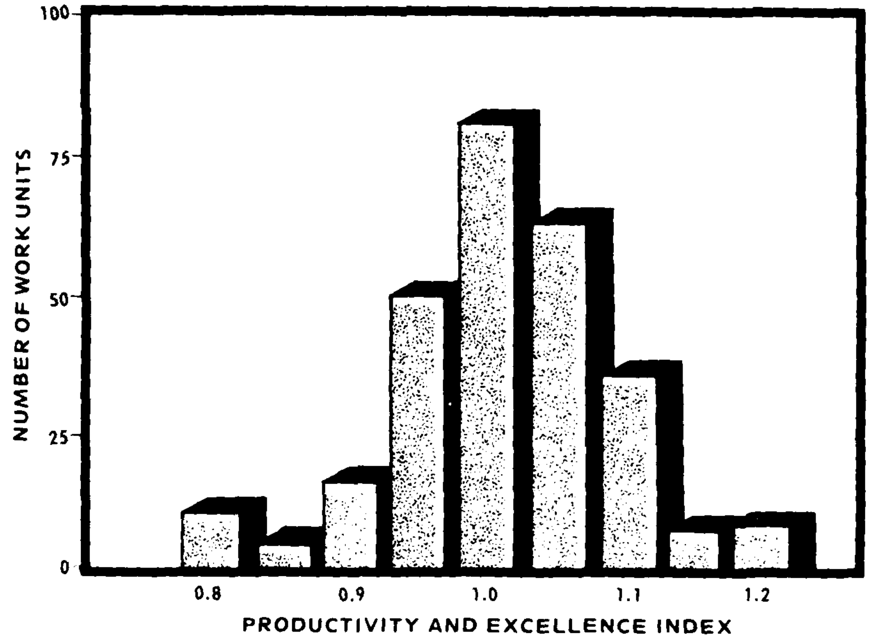
Knobs

Having learned something about the health of his organization, the laboratory director is now anxious to manipulate one or more knobs. As a prerequisite, the director must first know the initial position of the knob and then track the position of the knob as a function of time. This introduces additional reporting requirements: For each knob, status information must be collected.

There are dozens, or perhaps hundreds, of knobs available to the laboratory director. Of these, only a few have strong and predictable influences on the status of the laboratory. The director must focus on these few and resist the temptation to collect information in every knob on the chance that he "might need it someday." In my opinion, there are probably no more than a half dozen key knobs. The knobs listed in Table I deal with allocation of resources and represent a good point of departure.

As noted earlier, productivity and excellence are not single-valued functions of the position of a knob. Moreover, the process of operating one knob almost invariably perturbs the entire system and may require reoptimization of the positions of all other knobs.

FIGURE 5



Other Useful Indicators

In addition to the positions of the knobs, the laboratory director should monitor a few additional key variables that are strong indicators of the health of the organization. Table II lists a few such indicators. Note that these indicators are strongly related to productivity and excellence, that they are usually double-valued functions of productivity and excellence, and that they may be considered to be "weak" knobs.

Awards and Rewards

Crucial to the effectiveness of the award-fee contract is the existence of the fee; the contractor is motivated to excel by the realization that the magnitude of the fee awarded will be proportional to his productivity and excellence. A similar situation exists in the laboratory environment. Productivity and excellence in this environment are recognized by awards and rewards broadly classified as organizational on the one hand, and as individual on the other hand. It is general-

TABLE I
Key Knobs

- **ABSOLUTE ALLOCATION OF RESOURCES**
- **RELATIVE INVESTMENT OF RESOURCES IN BASIC RESEARCH, APPLIED RESEARCH, EXPLORATORY DEVELOPMENT, ADVANCED DEVELOPMENT AND ENGINEERING DEVELOPMENT**
- **RELATIVE INVESTMENT OF RESOURCES IN IN-HOUSE AND OUT-OF-HOUSE WORK**
- **RELATIVE NUMBER OF SCIENCE, ENGINEERING, TECHNICIAN, AND OTHER PERSONNEL**
- **RATIO OF RESOURCES DEVOTED TO OVERHEAD TO RESOURCES DEVOTED TO DIRECT MISSION WORK**

TABLE II
Other Potentially Useful Indicators of Productivity and Excellence

—RATIOS OF PAID AND UNPAID OVERTIME TO REGULAR TIME

—FRACTION OF PERSONS RECEIVING INCENTIVE, ACHIEVEMENT, AND OTHER AWARDS

—FRACTION OF PERSONS WHO MOVE WITHIN, INTO, AND OUT OF THE ORGANIZATION

—DEMOGRAPHICS IN A BROAD CONTEXT: TIME IN GRADE, DISTRIBUTION AMONG GRADES, EDUCATIONAL LEVEL, ETC.

ly perceived that organizational awards have little motivational value. Individual awards, on the other hand, are prized by the recipients and provide significant incentives to co-workers; these include career advancement, monetary rewards, tokens signifying achievement, and actions that enhance prestige.

Career Advancement: Of all the rewards for performance, a promotion is the most coveted. There are two problems worthy of note. First, promotions can be expected only infrequently during a career; a young scientist or engineer entering the government s·rvice, for example, normally can expect no more than three or four promotions before retirement 30 or more years later. Second, promotions

are often associated with advancement in the organization; for many scientists and engineers, the prospect of leaving the bench and becoming a manager is viewed with sadness and uncertainty.

Monetary: Monetary awards, including step increases in pay and one-time bonuses, are more common than promotions, and are usually not associated with advancement within the organizational structure.

Tokens: Tokens include medals (often of considerable value), trophies and certificates, and are highly prized by many recipients.

Prestige: There are many diverse rewards that enhance the prestige of the individual. One of the most viable appears to be public recognition. Scientists and engineers are strongly motivated to present their works at technical meetings and to publish papers in the open literature. Thus, for example, authorization to present a paper at national meetings is a reward that enhances the prestige of a scientist and strongly motivates him to engage in work that is suitable for such exposure.

Given the existence of an award-reward structure, there is nevertheless a perception that the existing structure does not provide adequate incentives. Additional study of this area in the context of R&D management appears to be warranted.

Comments and Cautions

An initial assessment of the award-fee methodology suggests that it is well suited for evaluation of the productivity and excellence of individual work units and also of large aggregates of work units. The methodology is consistent with good management practices in that it demands thorough planning prior to beginning the R&D effort, and demands periodic review of the progress and excellence. In addition, the methodology emphasizes the analysis and assessment of key management indicators; the feedback provided by these indicators is vitally important to the manager as he contemplates operating the various knobs at his disposal.

Needless to say, as one contemplates using this (or any other) methodology, he must carefully study its advantages and disadvantages. If carried too far, the award-fee methodology could lead (1) to undue emphasis on the reporting process and (2) to overcontrol by the manager. Another potential hazard of this methodology is the chance that the manager will place implicit confidence in the numbers generated by the methodology, and fail to ask the penetrating questions concerning why the numbers have the values they do. The watch words must be "simplicity," "judgment," and "remember Cohn's Law!"

An interesting and potentially valuable application of the award-fee methodology is the evaluation and rank ordering of a group of R&D proposals

that are suggested for expenditure of resources. The methodology provides a technique by which the manager can compare the relative merits of proposed work units, even when they differ widely in objectives and techniques. Put in other terms, the methodology can assist the manager in determining the potential return on the investment for each of several proposed pieces of work, and in selecting the work unit that has the greatest potential.

In conclusion, it should be noted that this paper is not the first to address the question of quantitatively evaluating the productivity and excellence of a laboratory. I depart from previous authors on two points: In my view, such a quantitative evaluation is (1) desirable, perhaps even necessary, and (2) achievable. The next step is to apply the methodology to a real situation and test its effectiveness. ‖

Automatic Test Equipment: The Critical Need for Early Planning

82

George W. Neumann

Job satisfaction for the manager of a major defense system acquisition program lies in the successful deployment of that system. The fielding of the first production units may even be considered a cause for celebration. But how do things look a year later? Has the fielded system been fully accepted by the operational forces, or is it the subject of headlines, tagged as a system its operators would rather do without? Does the new system have problems because some vital logistics element was ignored? Is the system consistently "non-operable" as a result of the non-glamorous "ilities" (reliability, availability, maintainability) having received only token attention during development? This has all too often been the case, with predictable results.

Early planning for logistic support is vital for all modern systems. One of the more important elements of early support planning involves planning for the automatic test equipment used for the maintenance of complex electronic equipment. Such early planning is essential if field support of the system is to be adequate. This paper addresses the early planning and decision-making processes as they relate to automatic test equipment, and discusses some tools available for use by the acquisition manager. The potential payoffs to the program are a significant reduction in life-cycle costs and a gain in system readiness.

Need for Automatic Test Equipment

Electronic components are being used more and more frequently in all types of military systems, and with each succeeding generation the circuit complexity increases. This increased complexity, coupled with decreases in skill and retention levels among military recruits, makes manual trouble-shooting of sophisticated electronic circuits infeasible. Such testing cannot be done by junior enlisted technicians with a minimum of training; it can only be done through the use of automatic test equipment. By making equipment maintenance more effective, automatic test equipment reduces equipment down time, reduces the number of maintenance personnel required, and generally eases the logistical burden.

The Cost of ATE

The *Industry/Joint Services Automatic Testing Report* states that the services spend more than $3 billion annually on automatic test equipment. This includes computers, test station hardware, test programs, interface devices, and software.

George W. Neumann recently retired from his position as Technical Director, Test and Monitoring Systems Program Office, at Headquarters, Naval Electronic Systems Command. From 1971 to 1981 he held positions at Headquarters, Naval Material Command, where he was responsible for management of the Navy's Test and Monitoring Program. He was also Chairman of the Joint Logistics Commanders Panel on Automatic Testing. Mr. Neumann holds a B.S.E.E. degree from Maryland University, and an M.E.A. degree from George Washington University.

The versatile avionics shop test (VAST) system used in support of carrier-based aircraft costs $4 million each, with four systems required for each carrier. Other test equipment ranges in size down to units as small as a desk-top console.

The ATE costs for support of a system depend upon the type of circuitry used in the prime unit (digital, analog, hybrid), the complexity, fault isolation requirements, and other vital factors such as:

—Quality, completeness, and availability of prime unit design data package;
—Maturity of the ATE type to be used;
—The engineers employed to produce the test program sets.

The primary cost of ATE software lies in the development of the test program set (TPS). This consists of a test program tape, an interconnection device, test program instructions, and related documentation. The high cost results from the many sets needed for each weapon system. For example, more than 64 different test program sets support one Navy aircraft at the weapons-replaceable-assembly (WRA) level at an average cost of $150,000 per TPS. Shop-repairable assemblies (SRAs) average $60,000 each for the 529 SRA test program sets for this aircraft.

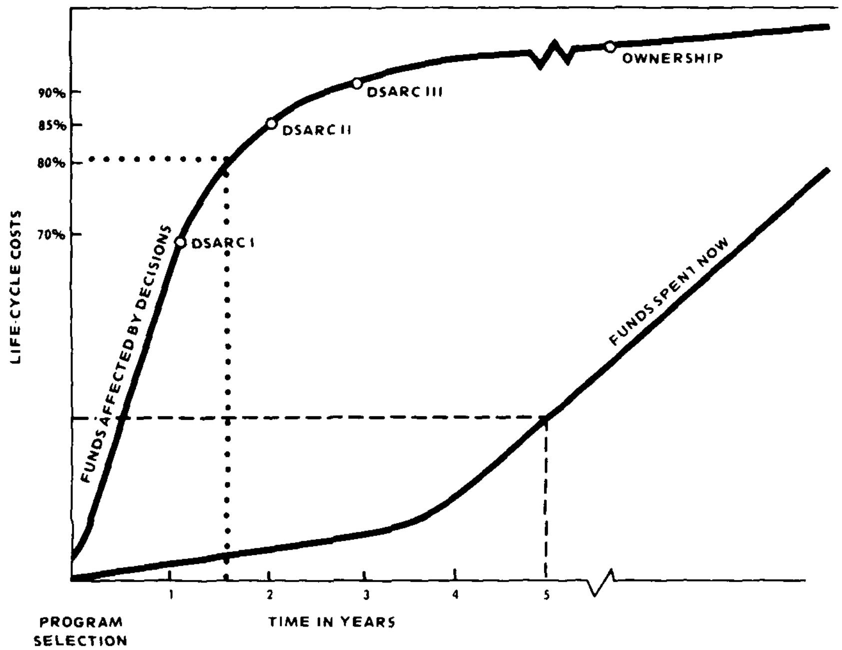
As the weapon system undergoes change during its service life, changes will be required in the automatic test equipment and attendant software. Unless strict configuration control is invoked, an uncontrolled situation with excessive costs can occur. Configuration management is a necessary discipline that should be an integral part of the weapon system management process. A difficulty that must be overcome is a tendency for ATE development to lag behind system development. Further problems and costs mount as changes to the weapon system require delays and modifications to the support systems. These problems must be recognized.

Early Planning for ATE

A significant percentage of the cost of automatic test equipment can be cut, but only if automatic testing is considered early in the system development cycle. The object is to reduce system down time in the least costly way. The danger that awaits the program is that ATE considerations can be buried under the problems of design and engineering for the prime system, and do not become major concerns until it is too late. Figure 1 illustrates the importance of making key decisions as early as possible. If the decisions regarding future support are delayed, the system life-cycle costs are already heavily committed. The natural tendency to try to save on acquisition costs by deferring spending to the deployed operation and maintenance funding stages must be recognized, and combatted by using total life-cycle cost as a system selection factor.

Early planning can help eliminate costly and complex interfaces by making available optional early design techniques that can optimize the testability of a circuit, component, or system without reducing performance. Good testability is an effective route to enhanced system maintainability.

FIGURE 1
DSARC Milestones and Related Commitments



One early decision that must be made involves the division of testing between built-in test (BIT) methods and separate automatic test equipment. How much BIT? How much ATE? Both have their roles and they operate synergistically when properly integrated. The integration of on-line (BIT) and off-line (ATE) testing can provide high levels of reliability, maintainability, and operational readiness at the lowest cost when proper trade-off techniques are used. The manager must know what is desired and the costs of accomplishing his goals, and must act early. Decisions regarding the division between BIT and off-line ATE must be made as early as the concept-formulation stage.

Sample Case

Automatic testing is an integral part of the missile launch control system of the Trident submarine. After ensuring that each missile is properly pressurized, that outer doors are open, and that all missile and launch functions are satisfactory, the launch control system launches the missile automatically.

The missile launch system automatically conducts the missile tests. When the "no-go" condition is found, built-in-test circuitry isolates the problem to either the launch system or the missile itself. Twenty-four equipment drawers (one per missile) containing 100 standard electronic modules (SEMs) of 16 differing types (2,400 modules in all) make up the launch control system. The BIT isolates the fault to a specific drawer, which can be removed and replaced in a test slot where it is checked by a special test computer. The test computer identifies the specific faulty card in the drawer. Thus, the combination of BIT and the built-in-test equipment (BITE) easily meets the established system requirement of 20 minutes or less for mean-time-to-repair/replace.

The cost of this system was a million dollars for BIT, 10 percent of the $10 million total system cost. Costs of BIT are often, as in this example, reduced because the contractor would have spent $500,000 for identical equipment required for in-house testing. The key to success and maximization of cost savings requires starting the design of BIT concurrently with prime system design, and considering the BIT for use during production testing. If costs are to be minimized, BIT must be an integral part of the prime system, and not just an afterthought.

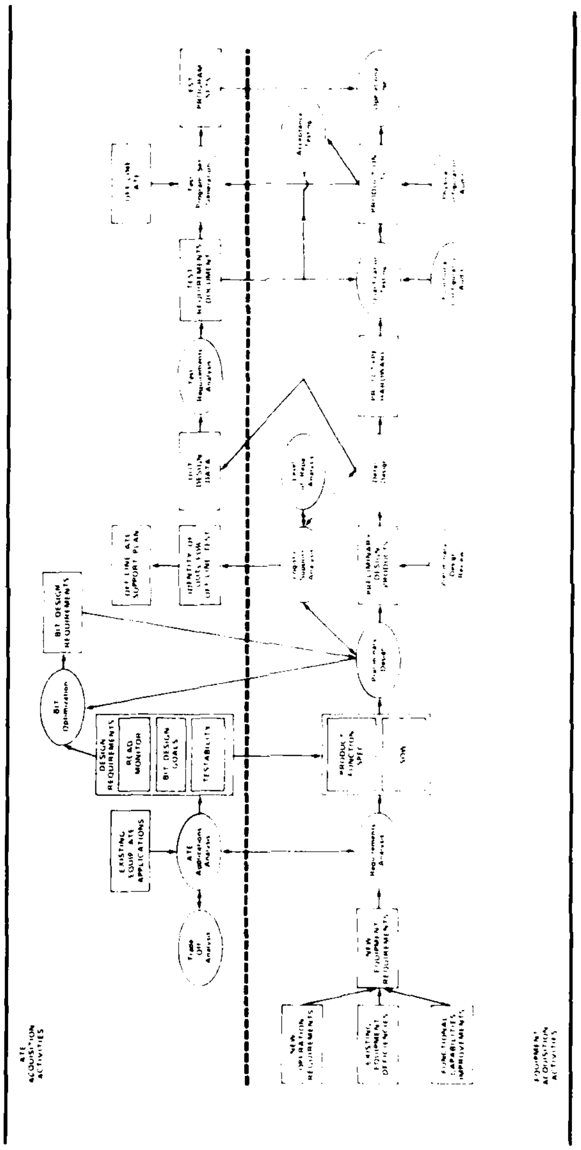
ATE Acquisition Process

The ATE acquisition process is a systematic series of actions to acquire the ATE and associated items necessary to support the system. The process is adaptable to acquiring items at the platform (ship, tank, plane), system (weapon system), or equipment level. Each major system is a composite of related units that are themselves candidates for automated testing. The ATE set that satisfies the needs of the overall system is viewed as part of the total support system. The subsystem relationships are established through a work breakdown structure of the major system. This provides a broad look at the overall ATE requirements (including BIT) and permits consolidation of test equipment requirements. Interface relationships must be identified early in the acquisition process and must provide a framework for managing the acquisition.

Automatic test equipment acquisition is identical to major system acquisition (conceptual, validation, full-scale development, and production phases). It is based on the realization that the effort is executed by a contractor or a combination of contractors and therefore concentrates on the generation of valid and timely contractual inputs. The procedures are, of course, tied to the defense department's acquisition policy with emphasis on matching DSARC milestones. Figure 2 depicts, in a simplified manner, the typical flow by showing relationships between the ATE acquisition and a supported new equipment item. In a major prime-system acquisition the process would include all DSARC review milestones.

The *conceptual phase* provides a basis for selecting a system that satisfies operational needs and provides options for further development. Management

FIGURE 2
Equipment Acquisition Flow Chart



activities in the conceptual phase are in the disciplines of ATE acquisition, system engineering, integrated logistic support, configuration management, test and evaluation, and procurement.

The system engineering process transforms operational needs into specific performance parameters and a preferred system configuration. The main system performance influences affecting ATE are the reliability and maintainability requirements. The time to repair or maintain a system defines the level of testing and the time to isolate faults for a test system such as VAST. Design engineering decisions concerning overall system configuration (especially decisions defining replaceable and repairable units) are the major drivers of ATE design parameters. The major system engineering elements involved are the operational and logistic requirements analysis, design trade-off analysis, system functional configuration, and the system characteristics.

Integrated logistic support activities are performed before system engineering to provide inputs and criteria for design trade-offs. The maintainability/maintenance interface is of primary importance to ATE at this stage of system procurement (maintenance planning includes requirements, design criteria, repair policy, test philosophy, and cost analysis while maintenance includes the concept, procedure, personnel skills, training, support equipment, provisioning, and documentation). Alternative system support concepts are developed based on the requirements analysis, estimates of current support capabilities, and identification of support problems peculiar to the system under consideration. Functional support requirements and a preliminary maintenance concept can be developed by using simulation techniques.

The objective of the ATE acquisition activity in the conceptual phase is the ATE support concept. The related ATE applications for a prime system are aggregated and provide the ATE support concept. The ATE support concept includes all interdependencies of the automatic testing application requirements. Applications range from operational monitoring (using BIT information) to circuit-board testers. A simplified framework of the automatic testing support concept can be developed by using a table listing the system functional elements from top-level down, vs. the automatic testing applications (readiness monitoring, BIT, off-line, etc.), performance/fault isolation levels (system, equipment assembly, etc.), maintenance level (organizational, intermediate, depot), and ATE candidates. The intersections of the matrix are expanded into a full-fledged ATE support concept covering all important issues.

Configuration management uses technical and administrative directives and monitoring to identify and document configuration item characteristics and control changes, and to maintain the change status. Specific configuration items are designated by the program manager and consist of hardware, software, or any of

their discrete portions that provide an end-use function. Usually, all hardware elements of a system selected for ATE support are designated as configuration items (CI). The functional equipment, made up of the replaceable units to be tested off-line, is also designated CI. Preliminary system specifications are used to identify and document the CI characteristics.

Test and demonstration events conducted during conceptual design must prove that the system and its support elements function as designed, and highlight weaknesses. The ATE acquisition is influenced through the demonstration and test of the design requirements for testability, reliablity, and maintainability. Automatic test equipment compatibility itself is part of the maintainability program requirements. The key document involved in demonstrating ATE is the integrated test plan, a part of the request for proposal (RFP)—appropriate portions are included in the preliminary system specification.

Most procurements with ATE acquisition impact are competitive and follow the normal sequence of preparing an RFP, evaluating proposals, selecting a source, negotiating a contract, then awarding the contract. The program manager or his ILS manager should participate in the preparation of the RFP and its eventual evaluation to ensure that ATE requirements are satisfied. Key documents involved include the acquisition plan (AP), and the advanced development RFP, which must be critically scrutinized at this time.

The *validation phase* verifies the results of the conceptual phase and allows system definition to the extent that the program manager can proceed to develop the detailed design. Significant events take place in ATE acquisition—system engineering, integrated logistic support, configuration management, test and evaluation, and procurement. Two distinct activities occur: (1) evaluation of alternative approaches, and (2) subsystem design. The key event for the program manager in this, as in every phase, is the DSARC milestone review. Several key documents must be prepared to support DSARC, including the following:

—Specifications
—Logistic support analyses
—Integrated logistic support plans
—Procurement requests
—Requests for proposal
—Budget requests
—Acquisition plans

Specifications must be reviewed to ensure that items vital to automatic testing are addressed. These include such cost drivers as testability, built-in-test, compatibility, documentation requirements, test language, and guidance for the critical test program sets. The logistics support analysis (LSA) must be updated to provide the latest information on sparing, configuration, storage requirements, manpower, personnel, and training. The LSA provides the guidance for optimized support and is a key document used in life-cycle costing.

The integrated logistic support plan provides milestone information needed to implement the support concept. It is concerned with test equipment procurement, test program set development and validation efforts, publications, sparing, and training. It is imperative that the milestone dates and plans for system support match the key dates for the system supported. Key integrated logistic support work statements are included in the full-scale development RFP, and a wide variety of topics must be covered by the acquisition manager at this time. The program manager should ensure that the bidder responds to items such as the following:

—General ILS approach (milestones, schedules, management)
—Specific ILS task identification (in terms of results)
—Integrated ILS network and flow
—Criteria for system selection and equipment for analysis
—Costing techniques
—Management plans
—Required documentation
—Installation, checkout, fitting-out plans
—Manpower plans

The better the RFP, the better the response. The program manager must tread a fine line between guidance and mandate to obtain everything he needs while simultaneously allowing room for contractor innovation. Particular attention should be given to development of the design requirements for testability and on-line test requirements. These will be included in the development specifications and the plans for off-line ATE support. Testability must be considered at this time. If it is not, there will be no testability considerations, or testing techniques with high costs will result. Testability includes functional modularization, test-point assignments, test-point access and arrangements, fault-isolation ambiguities, and disposal-on-failure criteria.

Full-scale engineering development begins with DSARC Milestone II and the development contract award. This phase will ensure engineering design completion, major problem resolution, and satisfactory completion of performance testing. The system, including support items, is designed, fabricated, and tested during engineering development. The output is a preproduction system similar to the final product, and test results that show the system meets the specifications. In the ATE area the logistic support analysis provides the heart of the design process. Operational testing is used to assess the integration of the hardware and the logistics support system. Failure can be corrected, but once a system has proceeded this far, correction becomes a costly process. Therefore, the ongoing test and support development are critical. The process of finalizing design and development of hardware must consider and firm up designs for testability and the optimum support philosophy. By the time DSARC III is scheduled, documentation must be complete and available to support the system. In addition to the

system and the contractual requirements produced by the contractor, the program manager is responsible for several other key documents and plans. They are as follows:

—Integrated logistic support plan (incorporating logistics element life-cycle costing, logistics support concepts, LSA)
—Logistics element test and development requirements (for test and evaluation)
—Specifications (detailed functional performance requirements)
—Test and evaluation master plan
—Provisioning and allowance documentation
—Logistics budgets
—Training plans
—Logistics support plan summary
—Procurement requests

Specific guidance has been published by the individual services to assist program managers in ensuring complete coverage of the required documentation. At this stage of acquisition, all loose ends must be tied. Confidence in the performance, operation, and support of the system should be beyond doubt, because any modifications could prove costly.

The thrust of ATE acquisition during full-scale development is establishment of the required off-line capability for each identified configuration item to be supported. Off-line ATE decisions are based on selection of the best options available. These are developed by matching test requirements with available test hardware. The priorities of choice are (1) existing militarized equipment, (2) existing commercial equipment, (3) modification of existing equipment, and (4) design and development of new equipment. These are, of course, generalized priorities. Guidance manuals are available dealing with selection of ATE equipment, and the individual services are currently involved in developing officially sanctioned ATE inventory lists for program managers. In addition to the equipment, the test requirements data are developed, and finally the test program sets are generated. Generation of test programs is the most costly and complex aspect of off-line ATE and significantly affect not only the original acquisition cost, but recurring life-cycle costs. Test program set maintenance is approximately 35 percent of total ATE life-cycle cost.

The production phase commences with DSARC Milestone III and the awarding of production contracts. The production phase provides the deployable systems, including their logistics support. Once full production begins, the principal efforts of the contractor center around engineering changes and change processing. Early establishment of configuration control management is a major concern, as is system installation, deployment, and production scheduling. Major ATE acquisition activities in the production phase center around test program set changes. Configuration control of the TPS is involved with the test program tapes, the interconnection devices, the test program instructions, and their related

documentation. Configuration control is a major task in the TPS area, and if neglected, costs can become astronomical. Experience and use of TPSs and the testers themselves will surface problems requiring modification and change, especially in the early years of deployment. Much of the program manager's time will then be spent solving short-term problems and modifying logistic plans to reflect real-life experience.

Support Organization for ATE

The program manager has help in handling ATE acquisition. The services have organizations to provide advice and assistance in all phases of the ATE life cycle: The Navy Test and Monitoring Systems (TAMS) Program Office (ELEX 08T in the Naval Electronic Systems Command); the Headquarters, Air Force Logistics Command Directorate of Equipment, Munitions and Electronics through the AFLC Automatic Testing Systems Manager at San Antonio Air Logistics Center (SA-ALC/MMI); the Air Force Systems Command (Aeronautical Systems Division) at Wright-Patterson AFB, Ohio; and the Army Communications Electronics Command (CECOM), Product Manager for Test, Measurement and Diagnostic Systems at Fort Monmouth, N.J.

These organizations are aware of past problems and the latest technology. They provide resources, tools, and people, and are capable of identifying, implementing, and monitoring solutions. Review of program plans by experienced ATE personnel can prevent headaches for the new program manager. The services not only produce handbooks, policies, and acquisition assistance, but also function as intimate parts of the Joint Logistics Commanders (JLC) Panel on Automatic Testing, providing guidance and identifying and attacking ATE problems. The JLC Panel publishes documents to save the acquisition manager time and money. Some are the *Navy Test Equipment Inventory Status, Acquisition Guide, Automatic Test Program Generation Guide,* a *BIT Design Guide,* and *Weapon System Acquisition Review Guidelines.* The Air Force has been developing a full set of guidance documents under the Air Force Systems Command modular automatic test equipment (MATE) program. The Army has developed *Test and Monitoring Diagnostic Equipment (TMDE) Acquisition Guides, Cost Analysis Guides, BIT Design Guide, TPS Acquisition Guide, TPS Design Guide,* and others.

Summary

The acquisition/program manager is confronted with myriad problems; central to his concern are costs, schedule, and performance. With the emphasis on total life-cycle costs, the manager is driven, by necessity, into active involvement with high cost, but high payoff, automatic testing. Successful use of automatic testing can help to ensure the success of today's sophisticated systems dependent upon electronics. The use of automatic testing for non-electronic systems is also

rapidly expanding, and significant new advances from successful R&D programs will soon be available. Awareness of the procedures and attention to automatic testing at the earliest possible time in a program can be a steppingstone toward a successful system. Assistance is available from the automatic testing community but, as always, the manager must shoulder final responsibility for the quality of the system.

A Cost Growth Primer

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Lieutenant Colonel John R. Power, Jr., USA

The rampant growth in the acquisition cost of most defense systems has been a great concern to the defense community for the past several years. From the pronouncements on Capitol Hill to the reports in the news media, criticism is focused on the Department of Defense for its rapid expansion of cost on major programs. The Reagan administration, with its new emphasis in military force modernization and readiness, is not ignoring the problem. On March 17, 1982, President Reagan sent a memorandum to Secretary of Defense Weinberger which stated, in part:

> We were concerned, as I am sure you were, to learn of the significant cost growth in a number of Defense programs . . . we need to make certain that the increase does not also signal program management weaknesses or technical problems in the Defense programs. . . .[1]

With that memorandum, President Reagan hurled a challenge to defense managers. He also requested the Secretary of Defense to assess the situation and initiate actions to reduce cost growth.[2] The reduction of cost growth is established as a goal, then, even in an era of increased defense budgets.

Just what is it that we are talking about when we set out to reduce cost growth? By knowing better the causes and ramifications of cost growth, we who must manage program cost will be better equipped to bring it under control. This paper will summarize the ways cost growth is identified, discuss the principal reasons why cost growth occurs, and describe how we report on program costs. It will conclude with some suggestions for managing in a cost-growth environment.

What Is Cost Growth?

The best definition of a term is usually the simplest one, and the definition former Deputy Secretary of Defense David Packard applied should confuse no one. He defined cost growth for the service secretaries as ". . . the net increased cost to the Government of items or services procured or to be procured."[3]

1. Ronald Reagan, Unpublished Presidential Memorandum to the Secretary of Defense. *Defense Program Cost Growth*, 17 March 1981.
2. *Ibid.*
3. David Packard, Unpublished Deputy Secretary of Defense Memorandum for the Secretaries of the Military Departments, *Cost Growth Definitions*, 5 August 1970.

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The term "cost growth" was coined only a year earlier by the Department of Defense. Prior to 1969 the operative word for something costing more than planned was overrun. Although "overrun" had a very specific meaning within DOD, a meaning relating to a cost-reimbursement form of contract that exceeded estimated or target cost, the term had become widely misused. The public, the media, defense critics, and many within DOD were using the term in a much broader sense, leading to misunderstandings and confusion.

An Office of the Secretary of Defense (OSD) level *ad hoc* committee was established in 1969 to investigate use of the term "cost overrun" and to determine what could be done to clarify the issue. It concluded that the term had three basic defects: (1) It actually had a narrow technical meaning; (2) it was widely used in the public and private sectors as having a much wider and imprecise meaning; and (3) the circumstances were such that the public use of the term was so wide and varied it was impractical to persist in trying to perfect the meaning and use of "cost overrun." Hence, the term "cost growth" was developed by the committee to supplant "cost overrun" as the term to describe total cost increases in defense programs.[4] This memorandum goes on to describe various categories of cost growth and to establish terms that are still in commnom use and will be discussed later.

Why Do We Have Cost Growth?

The causes of cost growth are numerous and vary from the performance of the economy as a whole (inflation) to poor management of an individual contract (cost overrun). Before examining the causes of cost growth, a point must be made that *cost growth is not always bad!* Although most of the literature, speeches, and discussion revolve around the tribulations of cost growth, there are desirable causes of cost growth such as acquisition of additional quantities or incorporation of essential new technology. Indeed, any specific incident of cost growth could be classified within the matrix illustrated by Figure 1 which the Army Procurement Research Office developed in a study of contract cost growth.[5]

Dr. Gardiner L. Tucker, former Assistant Secretary of Defense for Systems Analysis, maintains that the chief contributors to the cost-growth problem are uncertainty; competition, in industry and government; optimistically low and incomplete cost estimates; the lack of carefully defined acquisition requirements early in the process; and a tendency to view performance specifications and schedules as inflexible requirements.

The most basic cause is clearly uncertainty. The prediction of technical goals, schedules, and costs for 10-20 years into the future is a risky proposition at best.

4. Barry J. Shillito, Assistant Secretary of Defense (I&L), Memorandum for Assistant Secretary of the Army (I&L), Assistant Secretary of the Navy (I&L), and Assistant Secretary of the Air Force (I&L), *Contract Performance—Goal Technical Schedule*, 24 November 1969.

5. Robert L. Launer, Shirley H. Carter, and Harold F. Candy, *Contract Cost Growth in Major Army Programs*, U.S. Army Procurement Research Office, Fort Lee, Va., May 1973, p. 12.

FIGURE 1
Cost Growth Characteristics

	Acceptable	Undesirable
Planned	Acceptable Planned	Undesirable Planned
Unplanned	Acceptable Unplanned	Undesirable Unplanned

Nevertheless, the projections must be made and made in a competitive environment where various elements between and within the services compete for budget allocations and the industrial sector informally competes by avowing a low cost. These pressures serve to drive expectations up and estimates down thereby establishing an optimistically low starting point. Requirements for the system then tend to evolve and become refined as the development program matures adding new capabilities and commensurate cost along the way. And finally when the optimistic technical performance is hardened and documented the application of added dollars appears to be the only solution to meet what is not a need."[6]

Dr. Tucker's prime causes of cost growth provide a basic grouping from which to build and elaborate. In his paper "Should Cost Will Cost Must Cost" W. M. Allen provides insight into some of the factors already mentioned and adds a few ideas with his identified contributions to cost growth.

Competition, while usually considered a major means of reducing cost, is a major contribution to reducing estimates and thereby creating a lower base from which growth will inevitably occur. The competition comes both from the private sector and from within government. Figure 2 provides an example of the various forces working.[7]

Point F is the initial planning estimate by a contractor as the concept for a system begins to take shape. Before that estimate can be offered to the government as even a "ballpark" or budgetary planning figure, it must undergo some

6. *Ibid.*, pp. 57-59.
7. W. M. Allen, *Should Cost Will Cost Must Cost: A Theory* [illegible] Army SAFEGUARD System Office, Arlington, Va., June 1972, p. 12.

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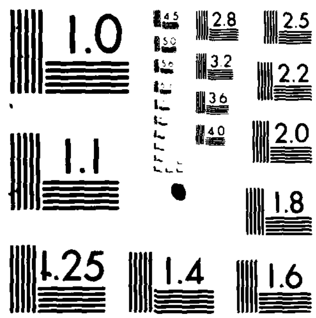

MICROCOPY RESOLUTION TEST CHART
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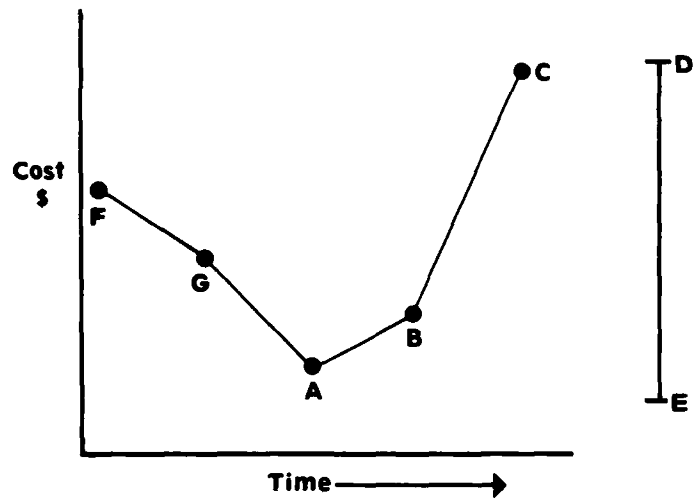
FIGURE 2
XYZ Weapon System



corporate review. Competitive pressure will then force the estimate down to G before it ever reaches the military action staff. The GA segment of the curve belongs to in-house government competition alone. How often have we heard "That will never sell!" in the initial planning and programming process? As the proposed program passes through various echelons of review the pressure is applied to reduce the estimate. The "preliminary estimate" which already had been subjected to some pricing policy is then forced down until it can be fitted into a budget. Point A then becomes the figure presented to congressional committees, a matter of public record, and the point of departure.[8] Clearly, the only way costs can go is up! And up they go, moving from A to B with the award of the contract. At that point many will decry the lack of competition as the cause of the modest growth experienced. Point C is the final cost of the program and the distance DE the amount of cost growth. That the growth occurred should hardly be considered remarkable.[9]

Why is it that we don't clearly see the post-contract rise in cost often resulting from the artificially low pre-contract estimate? The phenomenon of *requirements uncoupling* comes into play to mask the reality of the cost growth. The requirements uncoupling term applies to the idea that somehow the requirements

8. *Ibid.*, p. 27.
9. *Ibid.*, pp. 25–27.

vs. cost relationship is lost along the way and that a "have the cake and eat it too" demand (i.e., many requirements but little or no cost recognition) prevails. Therefore, rather than cutting requirements to cut costs, a viable management option, costs are simply ground down while requirements are preserved.[10]

The phenomenon of requirements uncoupling from cost can partially be attributed to the estimating process and the problem of the *point estimate*. Even though requirements evolve and a system matures in the development process, the cost estimate is an absolutely specific point which becomes institutionalized. While a specific dollar estimate should apply to a specific design, the design floats whereas the "cost estimate point" is fixed. The need for a point is apparent, however, for such applications as the planning, programming, budgeting system (PPBS) or a contract. There may even be an aspect of military decision-making present. How could the command position be "somewhere between A and B $?"[11]

There is almost an incentive to the military services to avoid determining what the program will really cost, focusing attention on what it "must cost." The "must cost" estimate is the perceived limit of affordability. "Must cost" is, in essence, what can be carried in the budget battles with "should cost" less than or equal to "must cost." What the services do, to have a program, is cut the foot to fit into the shoe. Allowing requirements uncoupling to take place, and arguing against any costing method that exceeds "must cost," are aspects of the process to initiate programs and to keep them under way.[12]

Perhaps Allen's most interesting thesis is that the root cause of the cost growth is the existing *monopsonistic* market condition. Monopsony is the situation in which there is only one buyer for several competing sellers, an apt description of the defense industry. This relationship supports the artificial forcing down of costs and prices and necessitates practices that permit costs to grow back, lest some major defense producers go bankrupt. Enforceable estimates (which must then be contractually enforced) can only come when either party has the option of walking away from the bargaining table.

Excessive documentation is a problem complained about often enough by contractors to bear consideration. That one should buy only that which it is certain can be used is a truism easier to state than decide or enforce. Perhaps more important is that the greater the deluge of documentation, the more likely it is that the key indication of program problems will slip by unseen. And the failure to notice and act on a problem indicator is, in itself, a problem indicator. Although we seldom admit it, *program management quality deficiencies* directly contribute to cost growth.[13]

10. *Ibid.*, p. 28.
11. *Ibid.*, pp. 32-34.
12. *Ibid.*, pp. 55-56.
13. R. W. Grimm, *Using Cost Analysis to Break the Overrun Habit*, Defense Systems Management College, Unpublished Report, Fort Belvoir, Va., May 1977.

Inflation has all too often been looked upon as the primary culprit in cost growth, thereby masking real program difficulties and management errors. Particularly in the current economic environment, however, inflation variances from that planned for is an important cause of cost growth. So also is *attempting to push the state-of-the-art* in technology. Infatuation with the latest innovation, coupled with a valid need for improved capability and an inherent optimism of designers has been the downfall of many a program. Yet, as each new program is structured there is a tendency to try to load it with every new item of technology. The problem of *concurrency* is a product of a similar optimism that the problems to be encountered will be minor and easily solved. Based on that expectation, production may be initiated prior to the completion of testing.[14]

Figure 3, developed by Martin Dean Martin,[15] was designed to focus on cost growth in a particular contract. The factors during preactivation, the pre-award phase, and activation, contract performance could apply to a program as well as a contract.

Martin's view of causal factors applying at different times relative to a contract life can be applied to a program life as well. The point of activation can be considered as entry into full-scale development as that is where the major commitment to a program with significant development investment begins. There are cost-growth drivers which operate in all phases however, necessitating some modification of the table. Figure 4 combines Martin's ideas with those discussed above, providing a summary of the factors that cause cost growth.

While the items listed in Figure 4 are certainly not exhaustive and do not include all of the causative factors in the cost-growth equation, they represent most of the reasons programs creep to even higher financial peeks. Having identified the causes of cost growth, many of which cannot be measured, it is useful to look at how we record and report on cost growth. The reader may find it interesting to note the minimal correlation between the cause and the report!

How Is Cost Growth Reported?

The *ad hoc* committee that coined the phrase "cost growth" in 1969 also provided definition by identifying nine areas in which cost growth might appear. Those nine subclassifications were:

—System performance change
—Engineering change (not affecting performance)
—Quantity change
—Contract added support

14. D. H. Webb, *The Study of Cost Growth of a Major Weapon System*, Naval Postgraduate School, Monterey, Calif., Dec. 1974, pp. 12–13.

15. Martin Dean Martin, "A Conceptual Model for Uncertainty Parameters Affecting Negotiated, Sole-Source, Development Contracts," Unpublished Doctoral Dissertation, University of Oklahoma, 1971, pp. 88–89.

FIGURE 3
Selected Causes of Contract Cost Growth

Preactivation	Activation
1. Cost Estimation a. Cursory cost analysis b. Lack of competition c. Projection and estimating process d. Contractor underpricing 2. Research and Development Specifications a. Concurrency of research and development with production b. Extraneous design requirements c. Faulty technical planning d. Inadequate task definition 3. External Environment Factors a. Budgetary constraints b. Uncertainty estimation 4. Internal Environment Factors a. Communication problems b. Risk analysis c. The negotiation process	1. Economic Factors a. Inflation b. Order reduction 2. Detailed Management Practices a. Lack of cost control b. Inadequate control of subcontracts c. Excessive reporting requirements 3. General Management Practices a. Changes in defense procurement policy b. Late delivery of government furnished property c. Program stretchouts 4. Technological Considerations a. Technological obsolescence b. Engineering changes c. Program reduction

—Schedule change
—Unpredictable change
—Economic change
—Estimating change
—Contractual price adjustment[16]

This list of nine subclassifications of cost growth, with their accompanying definitions, became the basis for cost-growth analysis and reporting to the Office of Secretary of Defense echelon. In essence, it was the forerunner of the Selected Acquisition Reports (SARs) now formalized and forwarded to key congressional committees quarterly.

Secretary Packard, in his memorandum of 1970, made some revisions to the list but kept the nine subclassifications. He combined "system performance change" with "engineering change," using the latter to represent all technical changes in the program. The area of contract cost needed to be more carefully

16. Shillito.

FIGURE 4
Causes of Cost Growth

CONTINUAL FACTORS	
• Inflation	• Uncertainty
• Budgetary Constraints	• Policy Changes
• Management Inefficiency	

PREACTIVATION	ACTIVATION
• Cost Estimating	• Technology Pressure
• Competition in Government	• Quantity Reduction
• Monopsony	• Program Stretchout
• Concurrency	• Lack of Cost Control
• R&D Specification Faults	• Poor Control of Subcontractors
• Requirements Uncoupling	• Excessive Documentation
• Poor Communications	• Late Government Furnished Property
• Negotiation	

defined, therefore a new classification was added. "Contract cost overrun (underrun)" became the repository of contract costs that exceeded estimates or targets, with "contract performance incentive" capturing adjustments in incentive and award fees. The "contractual price adjustment" classification from the committee was replaced by the last two categories.[17]

The categories discussed above provided the initial structure for the identification and classification of cost growth and reporting about its incidence, initially to OSD. These categories became the variance categories through which cost growth was explained in the Selected Acquisition Reports. Each quarter, the designated programs are summarized technically and in terms of schedule and cost and sent to Congress as mandatory program updates. The resultant data, particularly in the area of program cost, are the ammunition for the barrages normally fired by the media. If for no other reason, everyone in the acquisition

17. Packard.

management business should be aware of the "rules of the game" in SAR reporting.

The classification of cost growth from the Packard memo of 1970 became the categories of variances from established estimates until the revision of DOD Instruction 7000.3 dated April 4, 1979, which reduced the variance categories to seven. They are as follows:

—Economic Change—Solely owing to operation of the economy; escalation may have exceeded predicted rate; future rates increased.

—Quantity Change—Variations owing to buying different quantities than originally planned.

—Schedule Change—Changes in delivery schedule or period of performance.

—Engineering Change—Alteration of physical item or its functions.

—Estimating Change—Change or correction of error in prior base estimate; or adjustment in assumptions and techniques not provided for in the quantity, engineering, schedule or support variance categories.

—Other—Reasons not covered in other categories.

—Support Change—Change in cost for any item *not* in Flyaway Cost (incl. training, support equipment, data, spares, etc.).[18]

The categories of variance from the established base estimate, a point estimate institutionalized in a context where uncertainty prevails, provide a means of reporting growth in program cost. They would seem sufficient and cover the major areas causing cost growth, although the root causes are largely ignored. Indeed, DOD 7000.3-G advises that when the cause of the variance and the effect observed are at odds ". . . the analyst should give *priority to categorizing by effect*"[19] (Emphasis added). The ability to discern the real cause of cost growth in a program is further deterred by the "order of precedence" for computing variances. The required order, to ensure consistency within and between programs is (1) economic; (2) quantity; (3) schedule; (4) engineering; (5) estimating; (6) other; and (7) support. It should be observed that on occasion the real cause of cost growth is hidden by artificially forcing the cause of cost growth into one of the above categories. For example, if a program undergoes a major budget cut, forcing a program stretchout, the *effects* may be seen as economics, schedule, quantity, and support categories without recognition of the real *cause*.

What kind of relationship might there be between the real causes of cost growth and the way we report on it in the SAR? An examination of the two lists reveals the answer—very little. Of the 20 causal factors identified only four—inflation (economic), cost estimating (estimating), quantity reduction (quantity), and program stretchout (schedule)—are directly reported. All of the

18. DOD Instruction 7000.3, *Selected Acquisition Reports*, Washington, D.C., April 1979.
19. DOD Guide 7000.3-G, Preparation and Review of Selected Acquisition Reports, Assistant Secretary of Defense (Comptroller), Washington, D.C., May 1980, pp. 3-7.

other factors could be revealed in myriad ways. The pervasive pressures that push cost estimates to widely unrealistic lows are likely to appear as estimating changes. Those factors that reflect poor requirements definition, technical pressures, and uncertainty may appear as engineering changes. Where do policy changes (i.e., added reviews, increased testing, etc.) and management inefficiency come to light? Or, perhaps the more cogent issue is, do they?

A better understanding of the SAR does not end with a recognition that the report does not accurately reflect true causes of cost growth. There are other idiosyncracies of the SAR that should be recognized by both the casual observer and managers directly involved.

—*Real update is annual.*[20] The December SAR must correspond to the five-year defense plan (FYDP) updated by the President's budget. Those are the highest dollar amounts to be presented to Congress, hence major growth is only revealed once a year. Horror stories on cost growth often begin "In the last quarter above Defense costs. . . ."

—*Real forecasts are not revealed.* The budgets developed are escalated based on OSD indices that are significantly understated from historical inflation rates. Real growth is only revealed as the budget year in which it is needed approaches. Use of realistic escalation rates differing from official indices or even adjustment of past differences between forecast rates and actual experience requires Assistant Secretary of Defense (Comptroller) approval.

—*Programmatic decisions are buried.* Decisions in the PPBS or the congressional budget process, or other moves that may affect program goals, are often masked by reporting rules and artificiality. Notwithstanding schedule or quantity changes caused by budget decisions, the term "must cost" comes to mind. As long as feasible it is politically advantageous to espouse the "must cost" estimate.

—*Full impact of inflation is not visible.* The mechanics of SAR reporting preclude properly attributing growth to economics, the factor which represents inflation. The rules dictate the change be based on a change in the OSD indices. If an index is revised upwards, then a growth of a like amount can be reflected. That a particular industry, special material, or critical item far exceeds that rate is some other kind of variance—but not economic. As a result, economic changes are often buried as engineering changes, or most commonly, in estimating changes.

The SAR is prescribed only for selected major acquisitions, yet the product of the reporting is an attitude toward defense acquisition programs that tends to permeate the system. The smaller programs, which are not reported in this manner, are imbued with the "trend" mark of the SAR for the last quarter. And in many instances the reporting variance categories for cost growth become the standards for other programs.

20. DODI 7000.3, p. 4.

How Can We Improve the Situation?

It was not the purpose of this paper to offer an alchemist's solution to the cost-growth problem. It is clear that it is pervasive to the acquisition process and will not be solved short of a multipronged attack on philosophies and methods of operation. There are, however, steps that can be taken by program managers and the military commands responsible for development that could improve understanding of the problem, its complexities, and its nuances. The recommendations offered here may be something less than scholarly, but they are imminently feasible and useful.

—*Recognize the concerned audience.* Virtually everyone who is part of the "military-industrial complex" follows media reports on weapons system cost growth. Almost all major newspapers include syndicated columnists who report the latest indicators of defense mismanagement. Seldom do reports describe the complete facts. It should be assumed that the audience has heard the rumors and wants to know the facts from a prime, "informed" source.

—*Present a credible analysis.* When cost growth is an issue that has some publicity, in print or otherwise, PMs and their representatives ought to have a chart in every presentation that lays out the problem and provides a credible supportable analysis. This is not to suggest that the SAR that goes to Congress should be refuted, but rather, that an assessment of what the report would have stated were the SAR idiosyncracies not operative should be provided. The difference between what report data are political and what data are inadvertently submerged by the system should be distinguishable by the program manager.

—*Educate commanders, managers, and staffs.* That a program has suffered cost growth is easy to discern, either from the public media or command message traffic. The cause of the growth or the workings of the system that generated the number is something less than readily apparent. Development commands ought to ensure that their personnel understand the essence of cost growth and the SAR system. These important employees would then be able to influence those they interact with in a positive way.

—*Development headquarters should publish SAR summary.* There are endless participants in the decision process for systems acquisition. The key players should be well informed of the major reasons for cost growth on a system, lest their decision be biased by a lack of knowledge. The development command (such as HQ, DARCOM, for the Army) should publish a summary of their SAR systems and an honest analysis of the contributors to cost growth. The summary would be provided the major staff directors and commanders. In this way, these individuals, as they interact with their counterparts, would operate from a position of strength and knowledge.

The problem of cost growth, called overrun or by its present name, has been a challenge for the managers of our nation's defense throughout our history. The

examination of the root causes of cost growth would lead one to believe the problem to be inherent to the defense systems accquisition process. Reporting of cost growth appears to mask the true causes of the problem, preferring to address the ramifications measured. What is the potential to correct the situation? The Reagan administration has set forth the challenge. It is now up to defense managers to create a credible system which can stand the test of a 10–20 year development cycle. This is one challenge that must not be avoided.

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P^3I—Help in Reducing Weapon Systems Costs

Lieutenant Commander Marlene M. Elkins, USN

In the last few years there has been growing concern over the increasing cost and acquisition time of new weapon systems; cost overruns appear to be the rule rather than the exception, and 12 years is considered average for fielding a new system after initial identification of the need. On March 2, 1981, Deputy Secretary of Defense Frank C. Carlucci directed that a study group investigate the acquisition process with the primary objective of streamlining the process. Mr. Carlucci stated that "The Secretary and I are determined to reduce substantially cost overruns, deploy adequate quantities of needed systems that are operationally effective and ready, and do this in the shortest possible time."[1] Among the decisions made by Secretary of Defense Weinberger as a result of this study was to implement the pre-planned product improvement (P^3I) concept in an attempt to reduce unit cost and decrease acquisition time.

What is P^3I?

Pre-planned product improvement has been defined as "a systematic and orderly acquisition strategy beginning at the system's concept phase to facilitate evolutionary cost-effective upgrading of a system throughout the life cycle to enhance readiness, availability, and capability."[2] The idea of P^3I is not new, but is a well-established practice in the commercial sector, particularly the commercial aircraft industry. From the moment a new aircraft is designed, provisions are made for growth. Such provisions include design of critical components to take increased loads, and increased engine thrust anticipated to be needed in the future.

The next question is "How is P^3I going to improve the acquisition process"; i.e., why do we in DOD need to be concerned, and how is it different from what we are doing now?

1. Deputy Secretary of Defense Memorandum, Subject: Improving the Acquisition Process, 30 April 1981.
2. Hy Lyon, "Pre-Planned Product Improvement," *National Defense* (American Defense Preparedness Association), January 1981.

Editor's note: The subject of P^3I has taken on new significance with its use having been mandated as part of the DOD Acquisition Improvement Program (Action 2). For more on P^3I see "A Cultural Change: Pre-Planned Product Improvement" in the upcoming summer issue of *Concepts*.

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The High Cost of High Technology

One of the problems we have in acquiring new systems today is the ever-increasing cost of high technology. The drive for complex, state-of-the-art weapon systems is a natural tendency of Americans, who have a cultural upbringing that causes them to expect the best that is available, right now—both in consumer goods and in defense-related items. This has been called the "better mousetrap syndrome."

We know that the United States is a technological leader, and we demand capability—which may not be required for the immediate need—merely because it appears feasible. The Soviets rely on the concept that "better is the enemy of good enough." We Americans tend to scoff at this philosophy, but when we examine the balance of conventional forces, the Soviets are usually considered to be superior. Although individual Soviet weapon systems may be technologically inferior to ours, they do perform the stated mission and can be economically produced in such numbers that the United States is currently at a distinct disadvantage.

The current acquisition environment poses three primary sources for high-cost, high-technology systems. The first is the user community, which often states requirements in terms of desired technology. Instead of defining a need in terms of a mission end-result, users describe a desired system; e.g., "We need an umptifratz with a 'Widget A' seeker that will travel X miles per hour." Usually these requirements are based on knowledge that "Widget A" is being researched for possible application in a weapon system by some laboratory. This is not to say that users gold-plate their requirements, but that they want a desirable feature in advance of its being economically reasonable.

The second source is the engineering community. During a design development, engineers generally are highly optimistic and have a can-do attitude for the practically impossible. Their reputation is at stake, and by reputation American engineering is always at the leading edge of the state-of-the-art. Thus, there is a tendency to overdesign a system and expect any problems to be easily overcome during development—"If we tweak this gadget here, or if we use this special blend of materials, this system will then be a real hummer." Unfortunately "tweaking" and "special blends" are usually expensive and add to the risk of failure.

The third source is contractor competition. Obviously, each competitor wants to win; therefore, the tendency is to propose the system that will appear most attractive to the government. If the proposal does not push the state-of-the-art, then the contractor risks being considered inferior; he knows the government prefers "better" over "good enough." Unfortunately, these "better" proposals imply higher risk of achievement, which translates into higher contract prices or cost overruns further down the road.

It is the budget constraints and the need to upgrade our readiness *now* that have given impetus to the concept of P^3I. We can no longer afford the delay

caused by the desire to field the "perfect" weapon system the first time. The challenge is to accommodate the desires of the users and the engineers for eventual incorporation of the latest state-of-the-art technologies (which make the contractors' proposals competitive and attractive to the government) and in the meantime, provide for a relatively low-risk, less time-consuming system development project. This challenge is met by pre-planned product improvement practices, which also result in extending the effective operational life of the systems.

Early Planning Is the Key

The principal difference between product improvement (PI), planned product improvement (P^2I), and pre-planned product improvement (P^3I) is in the phase during which improvements are planned. Product improvement occurs after the fact; i.e., the system is in the field, and an improvement is designed and retrofitted to the existing system. In planned product improvement, the system is in full development; an improvement is designed for fit at a later time. In pre-planned product improvement, the system is in the concept phase, no firm interfaces or specifications are present, but plans for incorporating improvements at a later time are developed before the design is set. Awareness of new, developing technology allows the planning of future improvements before the system and interfaces are set in concrete and allows the new technology to be incorporated at a time when the technology is less risky and expensive to apply. In the meantime, a system is fielded in a shorter time because design stability is achieved at an earlier date; cost is reduced because development is less risky; support and maintenance are better defined for both the present and future; and readiness to meet an immediate threat is achieved. In the future the planned improvements can be incorporated at the optimum time against the threat-of-the-day and without designing a new weapon system from scratch.

Thus, the primary objectives of P^3I are as follows:

—The reduction of total system cost;

—Longer system lifetime before obsolescence;

—Reduction of initial risk;

—Higher technological performance during system lifetime through more rapid fielding of technological advances.

With these objectives in mind, it is apparent that this concept cannot be applied to every new system development. The concept is geared to a modular approach where growth is planned at subsystem levels. The major segment of technological change and dynamism in the 1980s appears to be at the subsystem or component level where pre-planning improvements are likely to be most effective/successful. Implementation of the P^3I concept in system development is more than just reserving weight and space for future subsystems; the chief concern is *management* of interfaces and overall architecture. The goal is to design the future system enhancements around rates of obsolescence. This implies a

basic system design such that components can be broken out for development and procurement at differing rates and times. Extraordinary configuration management is necessary. Control must be applied to subsystem boundaries, space, weight, power, movement, center of gravity, electromagnetic emission, and the logistics support system.[3]

The risk reduction implicit in P³I can be seen in the following example drawn from an article by former DOD and current defense industry executive Norman R. Augustine. If a new system is prepared that is based on six new subsystem developments, each of which has a 90 percent probability of success, then the likelihood of failure of the whole system development is about 50 percent.[4] On the other hand, if the new system used two or three existent subsystems with proven success, then the design is more stable and less risky—the probability of failure drops toward 25 percent. Planning for replacement of the existing subsystems when the technology has been proved will then upgrade the system at minimum risk. Initial unit cost should be less with the reduced risk, and funding for the upgrade can be provided in a more controlled manner with the definitive planning done early in the program.

Pre-planned product improvement has been used to some extent by the military. An example is the shoulder-fired anti-aircraft missile Stinger, which was designed from the outset to accept the more advanced post-seeker—not available at the time of initial development—at a later date. Other weapon systems which have used the principles of P³I or which will make use of this approach, are the Pershing missile, AH-1Q Huey/Cobra, Navy FJ-4 Fury, F-14 Tomcat, M60 tank, and the Spruance-class destroyers.

Some Disadvantages

Several disadvantages of using a P³I approach to weapon system development have been brought out during discussions in workshops on the subject. These include logistics problems associated with maintaining multiple configurations in the field during the phased upgrading process; the threat that upgrading existing hardware poses to obtaining legitimate new-start approaches; and the problems of handling competition in the contractual aspects of P³I. These problems can be overcome, however, with firm configuration control, sound reasoning and planning, and a genuine team effort by government and contractor personnel. The consensus of those involved in the workshops was that none of the problems posed are insurmountable. Perhaps the biggest stumbling block to widespread acceptance of P³I is the implication that a penalty may often have to be paid in the

3. Joseph F. Grosson, "P³I Competition, Standardization, and Systems Engineering," *National Defense* (American Defense Preparedness Association), January 1981.
4. Norman R. Augustine, "P³I: An Idea Whose Time Has Come . . . Again," *National Defense* (American Defense Preparedness Association), January 1981.

TABLE I
Criteria for P^3I (Compared to New Start and PI)

	P^3I	NEW START	PI
MOTIVATION FOR CHANGE	PLANNED FOR EACH UPGRADE	FORECAST LIFE OF ENTIRE SYSTEM	IN REACTION TO EVENTS
PREPARATION FOR CHANGE	R&D ON SELECTED COMPONENTS	R&D ON ENTIRE SYSTEM	SERENDIPITY -TECHNOLOGY BASE BREAKTHROUGH, NEW THREAT, OR DEFICIENCY
ORGANIZATION FOR CHANGE	REPLACE MODULE	REPLACE ENTIRE SYSTEM	COMPLEX INTERFACES MUST BE RESOLVED
DESIGN LIFETIME	DIFFERENT FOR EACH MODULE	MAXIMUM FEASIBLE FOR ALL COMPONENTS	WHATEVER IS AVAILABLE AT TIME OF PI
PERFORMANCE RELATIVE TO SOA THROUGH SYSTEM LIFE	ON AVERAGE, CLOSEST AVAILABLE SOA	HIGH AT START, ERODES AFTER DESIGN FREEZE	CATCH-UP MODE - FARTHEST FROM SOA
PROCUREMENT PLAN	FOR DEFINED MODULES	FOR ENTIRE SYSTEM	AS NEEDED
CONFIDENCE IN MEETING COST AND SCHEDULE	HIGH DUE TO MANAGEABLE NO. OF CHANGES	POOR YIELD DUE TO LARGE NO. OF SUBSYSTEM CHANGES	IS OFTEN IN RESPONSE TO PREVIOUS FAILURE TO MEET GOALS
CONFIDENCE IN THREAT PREDICTION	HIGHER DUE TO SHORTER TIME FRAME	POOR BECAUSE OF LONG RANGE OF PROJECTION	IN REACTION TO THREAT CHANGES
BUDGETING APPROACH	FUNDING WEDGE PROVIDED AT EARLY TIME	SPECIFIC ACTIONS FUNDED IN ADVANCE	NO ADVANCE FUNDING PROVISIONS

initial configuration of a new system in order to make the necessary provisions for future growth; i.e., fielding systems that won't contain all of the most advanced technology and desired capabilities.

Table I illustrates the features of P^3I, new starts, and PI (P^2I is incorporated in the P^3I concept). It should be noted that each approach is appropriate for different cases; i.e., no single approach can be used for all weapon system developments.

Summary

At the outset of a new development program, P^3I provides the flexibility to incorporate future advancements without violently disrupting the original design. The modular baseline configuration design permits growth to meet the changing threat and allows the incorporation of significant technological or operational opportunities at appropriate time intervals. The baseline technological risk will be minimized and lead to earlier deployment with reduced unit cost and less-likely cost overruns.

The major obstacle to acceptance of this philosophy is the cultural mind-set of the user and engineering communities toward using advanced technology regardless of the risk and cost of developing that technology. "In this regard, it is important to note that the contribution of technology to our forces must be measured for equipment in the *field* rather than in the *laboratories*; wars are not fought with equipment which exists only in the laboratories."[5]

5. Lyon.

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Competition: Does It Lower the Cost to the Government?

Major Robert J. Kruchten, USAF

Although many people tend to view competition solely in terms of lower prices,[1] such a definition is too restrictive. Webster defines competition as "effort of two or more parties to secure the business of a third party by the offer of the most favorable terms." Presumably because competition offers the most favorable terms, it has been strongly advocated in official policy.

The Office of Management and Budget (OMB) Circular A-109 directs each government agency to ". . . depend on, whenever economically beneficial, competition between similar or differing system concepts throughout the acquisition process."[2] The Department of Defense (DOD) implemented A-109 in DOD Instruction 5000.2 by directing that competition be ". . . introduced in the concept exploration phase and maintained throughout the acquisition cycle as long as economically practical."[3] Unfortunately, some people assume all competition is economically beneficial without actually examining the total cost to the government of specific examples.

The bulk of DOD's procurement is for major weapon systems and associated equipment. Within DOD, "competition is essentially limited to design and technical competition in the development phase of a major weapon system"[4] and, although such a competition may not select the lowest-priced offer, a frequent assumption is that the competition gives the government a lower price than could be obtained by a sole-source procurement.[5] This assumption should be critically examined on a case-by-case basis before justifying competition as the most "economically beneficial" method of procurement.

This paper examines competition in the DOD acquisition process. Specifically it questions some of the assumed price advantages of competition when applied to full-scale development contracts.

1. Michael D. Rich, *Competition in the Acquisition of Major Weapon Systems: Legislative Perspectives*, U.S. Air Force Project Rang R-2058-PR, November 1976, p. 7.
2. Office of Management and Budget Circular A-109, *Major System Acquisitions*. April 5, 1979.
3. Department of Defense Instruction 5000.2, *Major System Acquisition Procedures*, March 19, 1980, p. 14.
4. Ralph Hileman, *Proposals Preparation and Source Selection*, AIAA Seminar by Hy Silver, October 9-10, 1975.
5. J. A. Muller, "Competitive Missile Procurement," *Army Logistician*, November-December, 1972.

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Cost and Competition

It is difficult to measure the cost savings or price advantage of competition. Intuitively, any competition with price as a selection factor should have lower bid prices, but low bid prices do not necessarily equate with a cost savings to the government. For example, a cost-reimbursable contract may be awarded for full-scale development (FSD) at a low target price (caused by competition), but the contractor may have high actual costs and the product may have problems when the contractor tries to limit his cost growth. In this case, the initial competition cost savings are somewhat negated because the low initial target price was unrealistic and ultimately contributed to the increased government costs through overruns and a deficient product.

In another example, a contract may be awarded for FSD at a low target price (again caused by competition), but the cost of changes and production (negotiated as sole source) may be quite high. In this case, the initial competition cost savings are somewhat negated since the low FSD price was a means toward winning a production contract and the total cost to the government is not necessarily reduced. Lastly, a contract may be awarded for FSD at a low target price (caused by competition), but the contract price may escalate owing to schedule changes, technical problems, government-furnished equipment (GFE) problems, etc. In this case, any competition savings are difficult to segregate from other contract costs. Thus, any ultimate savings from competition are obscured by future changes, original bids (buy-in), technical problems, and government problems (GFE, etc.).

Although competition cost savings are difficult to document for FSD contracts, they have been documented for production contracts. In one study, 16 systems were studied.[6] Each of these systems had been originally produced on a sole-source basis and was then competed. This study showed that the intitial cost reduction due to competition appears to be an average of 45.8 percent. However, that savings is merely the difference between the original sole-source unit price and the competition unit price. Lovett and Norton correctly point out that the sole-source price would normally be reduced as production continues because of normal learning curves. After including the learning-curve factor and some of the competition-related expenses, the average savings dropped to 11.8 percent. Thus, this study showed a competition cost advantage of 11.8 percent. Although not directly applicable to FSD-type contracts, this type of study offers some of the best objective evidence of the savings that might be achieved by competition. A particularly interesting aspect of this study is that it attempted to include some of the costs of competition. Unfortunately, it could not include all costs to the government because some are very difficult to quantify.

6. Edward L. Lovett and Monte G. Norton, *Determining and Forecasting Savings from Competitive Previously Sole Source/Noncompetitive Contracts*, APRO 709-3, U.S. Army Procurement Office, U.S. Army Logistics Management Center, Fort Lee, Va., October 1978.

The total cost to the government is often overlooked when making the decision to compete for FSD. This probably occurs because one of the largest cost items of FSD competition is not a direct cost to the program. This indirect cost is the bid and proposal (B&P) cost. Typically, a request for proposal for a competitive FSD contract requires detailed technical and cost proposals. These proposals require the prospective contractors to do a preliminary design of the system and to spend a great amount of effort before contract award. For the losers, most of this effort is lost.

Defense industry speakers to the Defense Systems Management College have stated these proposals cost from 5 to 10 percent of the total program cost where the total program includes the FSD contract and all anticipated subsequent sole-source contracts (production, spares, etc.). This figure was also given during an AIAA seminar on Proposal Preparation and Source Selection (Figure 1).[7] The B&P costs are substantially paid by the government as part of allowable indirect costs and thus are not directly charged to a program. Specifically, the loser's costs of competition do not appear as part of the overall program costs.

There are, of course, other costs of competition that are paid by the government. These include the evaluation of multiple proposals, the negotiation with multiple contractors, the preparation of additional contracts, the additional audits/pre-award surveys, and the increased procurement schedule. Most of these costs will vary widely from program to program. For an FSD competition, the evaluation of proposals may be particularly costly and time-consuming because of the complex technical proposals.

Finally, competition may actually increase the ultimate life-cycle cost and degrade the system performance. Industry representatives and proposal preparation literature all describe the proposal preparation period as a time-critical intense period with industry attempting to guess just what the government really wants. This situation occurs primarily because government-industry dialogue is limited at that time. Although this atmosphere may stimulate innovation, I believe it also tends to create overly optimistic predictions and incomplete engineering. Because time is so critical during this period, the effort is usually broken into parts and resulting design may be poorly integrated, leading to increased life-cycle cost and degraded performance.

Discussion and Conclusions

Typically, DOD competes only the development of its major weapon systems with the subsequent production contracts being awarded on a sole-source basis.[8] Looking at a simplistic example shows the problem in achieving a cost savings in this approach.

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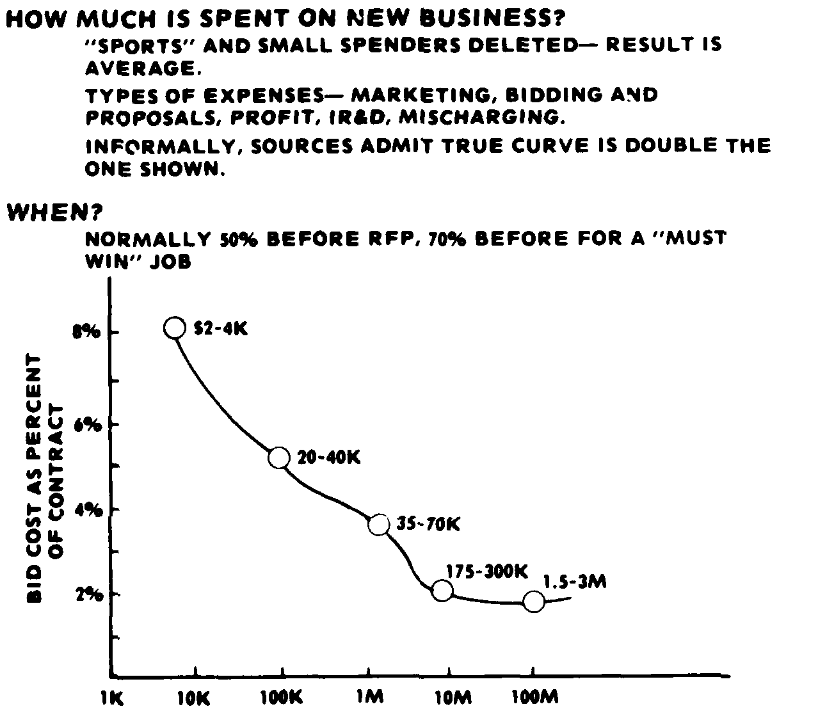
7. Hileman.

8. *Impediments to Reducing the Costs of Weapon Systems*, GAO Report to Congress, PSAD 80-6, November 8, 1979, p. 5.

FIGURE 1

Defense Industry Expenditures for New Business



If three contractors compete, each spending 5 percent for proposal/ marketing, etc.; and if it is assumed that the government pays 80 percent of these expenses; and if it is assumed that the winner's expenses are fully applicable to the program; then the government still loses 8 percent because of losers' expenses. Even though this simple example ignores other costs to the government and ignores the possible future benefits from some of the losers' efforts, it does show that competition may not offer real price advantages to the government. It also shows that the ultimate cost savings of competition is heavily dependent on the number of competitors and the effort each competitor spends to win the competition.

Recommendations

As stated earlier, competition should yield the most favorable terms to the government. However, it is important to understand that there are cases where competition is not desirable. This is especially true if cost is the primary reason for choosing competition. Certainly the total cost of a competition should be examined before deciding that competition is "economically beneficial."

Although cost is one reason for selecting competition as the best acquisition method, technical or political considerations may also come into play. Regardless of the reason for using competition, the acquisition agency should attempt to minimize the offeror's costs. Specifically, ways should be found to select a contractor based on his ability to perform rather than on his preliminary design and detailed cost data. The recent trends toward emphasizing a contractor's past performance would be beneficial, but a real savings could occur if we could award a contract by assessing each offeror's past performance, technological base (engineering capability, scientific skills, etc.), physical facilities, managerial system, and total estimated price (parametrically derived) without requiring a detailed technical proposal or detailed cost proposal. New contractors could present their proposed management system, their physical facilities, technological base and commercial performance record. The key emphasis would be to evaluate the contractor's ability to design and develop the system rather than his actual preliminary design. This would eliminate most of the present expense of proposal preparation.

Finally, some means should be found to tie both the winner's and loser's B&P costs directly to the program. This would create an incentive for program offices to write clearer requests for proposal with only essential information requested. It would also be an incentive to the contractor to hold down these costs because it would be a direct indication of his ability to control cost.

Summary

Although competition is sometimes desirable, the government incurs significant expenses during a competitive acquisition. These costs should be acknowledged and controlled as direct program expenses. By reducing the cost of competition in that manner we may get better systems due to more thoughtful design while achieving overall cost savings. ||

Risk Implications for Cost Growth in Weapon System Acquisition Programs

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William E. Thompson III

On March 27, 1794, the Congress authorized the construction of six large frigates that were to form the backbone of the newly-established U.S. Navy. The task of acquiring the ships was assigned to the War Department. Almost 17 months later, the keels were laid for all six ships. Shortly thereafter, owing to delays and cost overruns, the acquisition program was cut back to three frigates.[1]

Today, weapon system acquisition programs within the Department of Defense (DOD) are faced with the same problem—the ultimate costs of major programs are often substantially above the estimated costs on which they were justified and approved. In addition, this problem has not escaped notice outside the DOD. Over the years, there has been continuing criticism from both private and congressional sectors about the increasing costs incurred in weapon system acquisition programs. Whether the type and degree of this criticism has been justified is debatable, but there is no disagreement over the fact that significant cost growths have occurred.

Cost growth in weapon system acquisition programs can be defined as the difference between the ultimate, actual cost of a program and the initial cost estimate.[2] With this definition and a little thought, it is apparent that cost growth can occur for both "good" and "bad" reasons. As an example, consider the situation in which the system quantity is increased because of force expansions. This results in a cost growth by definition, but as the result of a "good" reason. Independent of the reason, however, cost growth does cause problems. Program cost estimates are used for a number of reasons, such as evaluating the alternatives to meet DOD needs, making decisions concerning the initial approval or continuation of programs, and planning for future needs. In addition, the Congress uses the estimated costs of major programs as one input to its assessment of national goals and priorities.[3] For the purposes of this decision-making, it is clear that any cost growth is undesirable.

The primary responsibility for controlling cost growth falls on one individual—the program manager. This paper will deal with the problem of how

1. Comptroller General of the United States,"A Range of Cost Measuring Risk and Uncertainty in Major Programs—An Aid to Decisionmaking," PSAD 78-12, General Accounting Office, Washington, D.C., February 1978.

2. Anthony S. Babiarz and Peter W. Giedras, "A Model to Predict Final Cost Growth In a Weapon System Development Program," unpublished master's thesis, School of Systems and Logistics, Air Force Institute of Technology, Wright-Patterson Air Force Base, Ohio, August 1975.

3. Comptroller General of the United States.

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the program manager can best accomplish his chartered task while controlling cost growth. It will address the problem from the point of view of risk, risk assessment, and risk management.

Risk and Cost Growth

For almost as long as cost growth has been a problem, there have been studies conducted and attempts made to categorize and explain its causes. For example, DOD instructions for preparing selected acquisition reports (SARs) include nine cost-growth categories for reporting cost changes:

—Quantity change
—Engineering change
—Support change
—Schedule change
—Economic change
—Estimating change
—Unpredictable change
—Contract performance incentives
—Contract cost overrun (underrun)

Without attempting to explain the precise definition of these categories, it is still worth noting that they have achieved some prominence because of the visibility of the selected acquisition reports, which are provided to Congress. However, it is also worth noting that, as stated in the SAR preparation instructions, these categories are *not* necessarily the causes of cost growth.

CAUSES OF COST GROWTH

The actual causes of cost growth for one program can be different from those in another program and can also vary within a single program over time. The possible causes are almost endless; for example, cost increases can result from the risk in technology development, poor planning and management, uncertainty in specifications and requirements, inflation, availability of funds, political considerations, and optimistic nature of some cost estimates.[4] It is apparent, however, that risk is a common trait inherent in all major programs, and it seems likely that risk is a significant determining cause of cost growth.

Considering the program manager's situation in managing a major acquisition program, the planning, managing, and controlling of the program is basically a continuing exercise in decision-making. In any decision-making process, the basic input is information. When all the needed information to select a decision alternative is known, there is no reason for a wrong decision. However, as the

4. Comptroller General of the United States; Guy W. Davis, "The Dilemma of Uncertainties Associated With Cost Estimating in the Project Manangement Office," Study Project Report, PMC 76-1, Defense Systems Management School, Fort Belvoir, Va., May 1976.

available information is incomplete, the resulting decisions involve varying degrees of uncertainty; the degree of incompleteness increases the possibility that a decision will be wrong.[5] Obviously, it is impossible to eliminate all uncertainty in decision-making. The process can be improved, however, by specifically considering the risks involved.

One study of risk and risk analysis in relation to weapon system acquisition programs led to the identification of four major categories of uncertainty within a program: target, technical, internal program, and process.[6] Target uncertainty involves a lack of knowledge concerning what end items are desired and what criteria should be used to evaluate them; stated another way, it is the uncertainty associated with reducing a military need to cost, schedule, and performance goals. Technical uncertainty involves solving technical problems; it addresses the question of whether a system can be developed at all or the degree of difficulty which will be involved in building it. Internal-program uncertainty involves how a program should be planned and managed; it is the uncertainty inherent in selecting a particular managerial strategy for dealing with a given problem. Process uncertainty involves the program's interaction with the external environment and revolves around uncertainty over the availability of resources required to complete the program, and the criteria and thresholds employed in program approval.

These categories help to clarify the pervasive nature of uncertainty in weapon system acquisition programs. For example, it is not uncommon to associate program risk primarily with technical risk. These categories make it clear, however, that technical risk is only the tip of the iceberg. Submerged are additional uncertainties, frequently having a far greater impact on the program and not always subject to control by the program manager.

IMPORTANCE OF RISK CONSIDERATIONS

Because cost growth is a major problem in weapon system acquisition programs and with risk identified as a significant cause of cost growth, it is apparent that the specific consideration and allowance for risk will help in the control of program costs. The problem of cost growth and its relationship to risk has been recognized within DOD for some time. In the late 1960s, Deputy Secretary of Defense David Packard focused on cost growth in weapon system acquisition programs as a problem that should be given priority consideration. The principal causes of cost growth were identified as optimism in program cost elements, cost growth from excessive development and production changes, failure to identify major risk areas, and excessive dependence on paper analyses. In his memoranda of July 31, 1969, and May 28, 1970, Deputy Secretary Packard directed the serv-

5. Babiarz and Giedras.

6. Robert R. Lochry, *et al.*, "Final Report of the USAF Academy Risk Analysis Study Team," USAF Academy, Colo., August 1971.

ice secretaries to identify areas of high technical risk, to accomplish "formal risk analysis," and to expand program management practices to include explicit consideration of risk assessment, risk reduction, and risk avoidance.[7]

Emphasis on the consideration of risk within the federal government and DOD has continued since Deputy Secretary Packard's initiatives. Office of Management and Budget Circular A-109, "Major System Acquisitions," requires the consideration of "methods of analyzing and evaluating contractor and government risks" as part of the acquisition strategy for major systems.[8] The DOD Directive 5000.1,"Major System Acquisitions," and DOD Instruction 5000.2, "Major System Acquisition Procedures," also establish policy and procedures to minimize the overall risk of systems development; DOD Directive 5000.1 requires that "commensurate with risk, such approaches as developing separate alternatives in high risk areas, experimental prototyping of critical components . . . should be explored."[9]

Risk and Uncertainty Concepts

To apply risk concepts to program management, it is necessary to develop a precise technical definition of risk. Most people have a relatively non-technical concept of risk; it means taking a chance or exposure to adversity or danger.[10] Consider, for example, the following study. A number of words or phrases are commonly used in the non-technical sense to represent risk or uncertainty, such as these 10 expressions: probable, quite certain, unlikely, hoped, possible, not unreasonable that, expected, doubtful, not certain, and unlikely. Some 250 business executives were asked to rank these 10 phrases in decreasing order of uncertainty. Table I gives the results for a typical group of 40 executives, the phrases being reordered in descending order of average rank. The third column shows the range of ranks given to each of the 10 expressions.

The variation in the range of ranks illustrates the considerable overlapping of ranks that occurs for many of the expressions concerned and thus the inconsistency between respondents. In fact, only three of the 250 executives produced exactly the same rankings. A further experiment with a smaller group, where the ranking was repeated about a month later, showed that the respondents were not consistent over time in their ranking of the same expressions.[11]

7. Memorandum from the Deputy Secretary of Defense to Secretaries of the Army, Navy, and Air Force, "Improvement in Weapon System Acquisition," Washington, D.C., July 31, 1969; Memorandum from the Deputy Secretary of Defense to Secretaries of the Army, Navy, and Air Force, "Policy Guidance on Major System Acquisition," Washington, D.C., May 28, 1970.

8. Office of Management and Budget, Circular A-109, "Major System Acquisitions," Washington D.C., April 5, 1976.

9. Department of Defense Directive 5000.1, "Major System Acquisitions," March 19, 1980; Department of Defense Instruction 5000.2, "Major System Acquisition Procedures," March 19, 1980.

10. Lochry.

11. P. G. Moore and H. Thomas, *The Anatomy of Decisions*, Penguin Books, New York, N.Y., 1976.

TABLE I
Rank Ordering of Expressions of Risk and Uncertainty

EXPRESSION	AVERAGE RANK	RANGE OF RANKS
QUITE CERTAIN	1.10	1-3
EXPECTED	2.95	1-6
LIKELY	3.85	2-7
PROBABLE	4.25	2-9
NOT UNREASONABLE THAT	4.65	3-7
POSSIBLE	6.10	3-9
HOPED	7.15	3-10
NOT CERTAIN	7.80	3-10
DOUBTFUL	8.60	7-10
UNLIKELY	8.75	3-10

The preceding example illustrates the need for a precise definition of risk and for the use of quantitative rather than qualitative expressions of risk. For a weapon system acquisition program, one definition of risk is the probability that a planned event will *not* be attained within constraints (cost, schedule, performance) by following a specified course of action. Uncertainty, on the other hand, is defined as incomplete knowledge. Uncertainty is distinguished from risk by the quantification of the risk in terms of a probability.[12]

SUBJECTIVE PROBABILITY

Most people in the systems acquisition business are familiar to some degree with the notions of probability and probability distributions. This familiarity is usually in terms of an expression of relative frequency. The relative-frequency concept of probability evolved from situations such as games of chance (e.g., throwing dice or dealing cards) where plays are repeated many times to produce a probability of occurrence for the various possible events. On the other hand, many of the events associated with a weapon system acquisition program cannot be given a relative-frequency interpretation.

For example, in the development of a system at a specific cost, the development process cannot be repeated a number of times to determine the probability of success. However, while an objective measure of probability in the relative-frequency sense cannot be obtained, the program manager has his own views about the development and its likely success. These feelings, quantified in probability terms, represent a subjective probability assessment. The concept of subjec-

12. Lochry.

tive probability has value in that it allows the decision-maker or expert to describe his feelings about the effects of uncertainty in defined and quantitative terms, and thus is able to incorporate his judgment explicitly into the decision process. The resulting numbers do not imply objectivity; as judgments differ, so would any subjective probability assessment. This does not invalidate the theoretical basis for subjective probability. Subjective assessments are based on the information available to the assessor at the time; as the same information becomes available to all assessors, their differing assessments should reasonably converge to a common figure.[13]

Considering Risk in Program Management

In making decisions, any program manager will consider risk, because considering the "likelihood" of success among the various decision alternatives is a necessary step in reaching a decision. The point is that, if not explicitly considered, risk considerations will be included implicitly in the decision-making process based on the overall subjective probabilities the decision-maker assigns to the alternatives, even though he may not think in those terms. Decisions have been, and can be, made successfully without explicitly considering risks. Such a successful decision-maker is likely to have an excellent "feel" for the subjective probabilities in the decision situation, so that his assessments and decisions are usually correct.

Before explicit consideration of risk is rejected in favor of finding a successful *ad hoc* decision-maker, consider that, as the decision becomes more complex, it becomes less and less possible to "internalize" all the factors involved in the decision, or to figure out the relationships among variables by a "gut feeling." Complex decision-making situations are common in program management; a failure to take risk explicitly into consideration is to depend solely on the resources and competence of the decision-maker. Explicit consideration of risks allows a much broader-based attack on the problem. A large, messy problem with many factors can be reduced to one where the issues are focused on fewer variables. The area within which judgment is required is more sharply defined; expert opinion can be brought to bear, and judgment on specific issues becomes more observable, more quantifiable, and less subject to other influences.[14]

RISK MANAGEMENT

Explicit consideration of risks can have significant value even if specific probabilities and quantitative risk-analysis methods are not used. The identification and evaluation of the program risks can be a valuable part of management infor-

13. Moore.
14. Erwin M. Atzinger and Wilbert J. Brooks, editors, "Compendium of Risk Analysis Techniques," AMSAA SP-4, Army Material Systems Analysis Agency, Aberdeen Proving Ground, Md., July 1972; Moore.

mation and can provide a basis for making major decisions. For example, recall the four categories of uncertainty discussed above: target, technical, internal program, and process. The consideration of a program in light of these categories can allow a clarification of the risks within a program and can provide risk-management alternatives to reduce or avoid risk.

The appropriate alternatives will depend on the categories of uncertainty that dominate the program. For example, if target uncertainty is predominant: (1) threat studies need to be continued during development; (2) performance requirements should be given in terms of a range rather than a single value; (3) a source for trade-off decisions with Office of the Secretary of Defense (OSD) authorities is desirable; (4) a restatement of performance requirements is needed after the start of development; and (5) operational prototyping should be considered.

If technical uncertainty is paramount: (1) model testing and development, production, or operational prototyping should be considered instead of paper analysis; (2) parallel development by more than one approach is needed; and (3) subcontractors with proprietary technology advantages should be available as subcontractors to all prospective contractors.

Internal program uncertainty requires: (1) maximum flexibility in program management; (2) high levels of communication among program managers; and (3) possible production prototyping.

Process uncertainty covers many unknowns and indicates: (1) the need for program approval to be clearly defined; (2) rapid program manager access to a higher trade-off authority; and (3) the program manager should conduct a continuing sensitivity analysis of possible impacts due to unexpected funding changes.[15]

RISK ANALYSIS

In situations where a formal risk analysis is appropriate, the basic steps involved are to (1) establish the significant uncertainties involved; (2) select a promising decision alternative based on these uncertainties; (3) assess the risk associated with the alternative; (4) generate other alternatives based on minimizing risk areas; (5) assess the risks for the new alternatives; and (6) continue until a satisfactory alternative is reached.[16] These steps, particularly the identification of important variables and the development and generation of alternatives, are similar to the planning and management functions of good program management.

Without risk analysis, normal management will plan and select a favored alternative in a decision-making situation; the incorporation of risk does not require a completely separate and distinct activity, but builds directly upon the existing framework of good management. For example, at the initiation of a pro-

15. Lochry.
16. *Ibid.*

gram, the detailed planning required by good management will develop the best possible acquisition strategy, lay out the details of the program in terms of a work breakdown structure and schedule, and develop a best estimate for the program cost. A formal risk analysis will build directly on this activity, assessing and aggregating risks to evaluate alternatives and suggest better ones. When the final alternative is chosen, the risk analysis will provide, instead of a single expected cost and schedule, a probability distribution for both schedule and cost.

Risk analysis, although not a science, has been the subject of numerous studies, with many specific techniques having been developed to assess risk, both in terms of individual program elements and in aggregating risks to the program level. There is a large body of knowledge within DOD concerning risk analysis in terms of various techniques and their application to specific programs. It is beyond the scope of this paper to attempt to catalog the various techniques available, and it is also not feasible to recommend any one technique, because the best procedures will differ with each program. However, to clarify the power and usefulness of risk analysis, it is worthwhile to review a generalized example.

Assume you are the program manager of a major program. The program has progressed sufficiently so that the major tasks are defined, sequenced, and milestones established. You decide to conduct a risk analysis of the present program, building on a network-schedule analysis that is just beginning. Working with the appropriate experts at the task level, risk assessments are made for the cost and schedule to complete the task in terms of a probability distribution. These assessments are generated through a variety of methods, such as group-assessment techniques, subjective probability, technological forecasting, and cost estimating. The probability distributions are then aggregated to the program level, using any of several computerized network analysis programs. The outputs of this process are probability distributions for the time and cost of the entire project and the probability that it will be successfully completed. This information can be easily used to determine the risk of completion within specified cost and schedule constraints. The joint probability distributions for cost and time can be displayed to show a joint-risk profile as shown in Figure 1. The curves on the graph are lines of equal risk. This graph will show not only the total program risk in terms of cost and schedule, but can also be used to determine the trade-off between cost and schedule on an equal-risk basis.

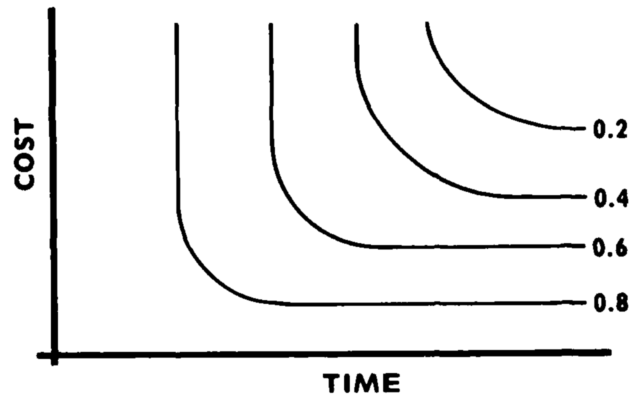
Risk and Acquisition Contracting

SOURCE SELECTION

One fairly specialized application of risk analysis has important implications for the program manager. Even if formal risk analysis is not pursued in other areas, risk analysis should be a significant part of any major contractual source selection.

The source-selection activity for a major contract in a development program involves substantial preparation and effort from both the government and the

FIGURE 1
Joint Risk Profile of Time and Cost



potential contractors. The quality of this initial effort is of paramount importance; ideally, it leads to the selection of the best approach to complete the contract by the best contractor at the "right" schedule and cost. The source-selection process sets the tone for future relationships, and the resulting contract is the basis for major activities and expenditures by the contractor to meet government objectives.

The importance of the source-selection process warrants special management attention, including the explicit consideration of risks. The DOD Directive 4105.62, "Selection of Contractual Sources for Major Defense Systems," states that "the solicitation shall require the competitors to identify technical risks and uncertainties and suggest realistic approaches . . . to avoid these risks . . . or reduce them to acceptable levels."[17] Compliance with this directive involves including a section on risk analysis in the request for proposal. The proposals provided by potential contractors will include the risk analysis of their proposed approach to the effort. This risk analysis provides another source of information for evaluating the various proposals. However, risk issues can only be considered in the evaluation if risk is included as a part of the criteria for evaluation set forth in the request for proposal.

Once the proposals are received from all bidders, the evaluation of proposals is begun. The typical method is to proceed based on a criteria breakdown structure developed from the more general criteria for evaluation. To include the evaluation of risk as part of the overall evaluation, it is necessary to include risk

17. DODI 5000.2.

as a section of the criteria breakdown structure. For example, in addition to evaluating the point value of a technical parameter for a proposed system, it is also necessary to evaluate the risk in being able to achieve that value. This evaluation of risk is based both on the risk analysis presented by the bidder and on the subjective assessment by the evaluation team. By including risk as an explicit part of the evaluation process, the overall evaluation of each proposal will include the risk as well as the effectiveness/efficiency of the proposed effort. Consideration of risks should lead to better source-selection decisions and will help highlight important areas of risk and uncertainty that bear watching during the actual contract performance.

CONTRACTING AND PROGRAM RISK

Once a source selection has been made and a major contractual effort is under way, an additional factor is introduced into the assessment and management of risk within the program. The existence of major contracts brings an entirely new set of players into the situation, and the existence of the contract document modifies the risks that are under the direct control of the program manager.

One major effect of contracting is a partial sharing of risks between the government and the contractor. This is particularly true in the area of technical uncertainty. For a given contract, the primary determinant of the risk-sharing relationship is the contract type. In discussing the choice of contract type, Defense Acquisition Regulation 3-401 states "the specific type of contract should be determined by the degree of risk in contract performance. When the risk is minimal or can be predicted with an acceptable degree of certainty, a firm fixed-price contract is preferred. However, as the uncertainties become more significant, other fixed-price or cost-type contracts should be employed to accommodate these uncertainties and to avoid placing too great a risk on the contractor."[18]

The choice of contract type determines the proportion of the total risk transferred to the contractor. The government, desiring to "avoid placing too great a risk on the contractor," must estimate the total risk involved in the effort. If the total risk is high, then a contract type that transfers a relatively small portion of the risk to the contractor is appropriate; if the total risk is low, then the majority of that risk may be transferred.

The total risk of a given effort obviously depends on the details of the effort, but it is often directly related to the phase of the program in which it occurs. In a program's early stages, there is usually a high degree of uncertainty and risk. As the program progresses, the uncertainty and risk is reduced by overcoming the unknowns. By the last phases of a program, uncertainty and risk have been reduced to a minimum. Conventional wisdom on the choice on contract types reflects this generalization—cost-type contracts are typically used early in the

18. Defense Acquisition Regulation 3-401, "Basic Principles for Use of Contract Types."

program, gradually transitioning to fixed-price contract types as the program nears completion.

For a contracted effort, both the program phase and the contract type are thus primary determinants of the amount of uncertainty and risk retained by the program office. The relationships of both these factors to contract cost growth were investigated by a study of contract cost growth in major Army programs.[19] A random sampling of 300 Army contracts, each exceeding $500,000, was examined in detail. The relation of contract type to program phase for the sample generally follows the typical pattern, as shown in Table II.

For this same Army study, the entire sample cost growth was found to be 52 percent from all causes. Reporting under the same categories used in the DOD selected acquisition reports, it was determined that the most significant cost-growth categories were quantity changes (30 percent), engineering changes (8 percent), and support changes (7 percent).

COST GROWTH AND CONTRACT TYPE

Relating this same sample data to contract type, the average cost growth experienced for each contract was 52.7 percent for firm-fixed price (FFP), 10.9 percent for fixed-price incentive (FPI), 117.5 percent for cost plus incentive fee (CPIF), and 50.2 percent for cost plus fixed fee (CPFF). For each contract type, the study also determined the predominant cost-growth categories. Considered with the program phase, this provides some indication of the major sources of risk and uncertainty. For CPFF contracts, the majority of cost growth (86 percent) occurred in the quantity-change category. Typically, this reflected the contracting of additional work, extending the period of performance. Because CPFF contracts occur most frequently in early program phases, the most likely primary cause of the cost growths is incomplete definition of contract requirements, reflecting both target and technical uncertainty (as defined above).

For CPIF contracts, the percentage of cost growth was substantially greater than for other contract types. The following cost-growth categories contributed a much higher percentage of cost growth for these contracts than they did for others: (1) engineering changes, 23.7 percent; (2) additional industrial engineering services, 14.2 percent; (3) economic changes, 1.7 percent; (4) estimating changes, 6.4 percent; and (5) contract overrun, 6.9 percent. The CPIF contract type is typically in the development phase of a program. This fact and the predominant cost-growth categories suggest that technical uncertainty is a major cause of cost growth. Once development has begun and technical problems are encountered, the results are increased costs owing to revisions in the technical approach and overruns.

19. Robert L. Launer, Harold F. Candy, and Shirley H. Carter, "Contract Cost Growth in Major Army Programs," AD PRO 007-3, U.S. Army Procurement Research Office, U.S. Army Logistics Management Center, Fort Lee, Va., May 1973.

TABLE II
Percent of Contracts by Contract Type and Program Phase

CONTRACT TYPE	PHASE	STUDIES	RESEARCH	DEVEL.	CUSTOM PROD.	MASS PROD.
FFP		—	8%	6%	58%	62%
FPI		—	—	15%	19%	26%
CPIF		5%	17%	43%	8%	10%
CPFF		95%	75%	36%	15%	2%

Fixed-price incentive contracts experienced the lowest average cost-growth rate for all contract types. The majority of cost growth occurred in the categories of quantity changes (58.2 percent) and engineering design changes (23.4 percent). As FPI contracts are particularly appropriate to early production, it should be expected that changes in quantity, early production problems, and changes dictated by operational use would result in cost growth.

The majority of cost growth for FFP contracts occurred in the categories of quantity change (76.8 percent), support changes (12.6 percent), and engineering changes (6 percent). Considering that FFP contracts are typical of production efforts, this indicates the importance of process uncertainty.

The risks in an acquisition program considered by the program manager are modified by the contracts for the system development. As discussed above, contractor involvement results in sharing of the risks. To the extent that risks are assumed by the contractor, they will *not* result in cost growth to the program manager (although the contractor may experience a cost growth). Because contracts typically require performance to a given requirement or specification, the risk assumed by the contractor occurs primarily in the area of technical uncertainty. The amount of risk assumed by the contractor tends to be relatively constant throughout a program's life cycle. The high risks early in a program are borne primarily by the government through the typical use of cost-type contracts. Toward the end of the program, although more of the total risk is assumed by the contractor through the use of fixed-price contract types, the total risk is much lower because many of the unknowns have been resolved. The other areas of uncertainty (target, internal program, and process) are generally not shared to a significant degree with the contractor. In fact, the existence of contracts can add elements of risk to the program in the area of internal program uncertainty, because the contractor is a major team player who is not fully subject to the program manager's control. Whatever the situation, the impact of current and planned contractual efforts on the program's uncertainty and risk must be considered in risk analysis and risk-management efforts.

Benefits of Risk Analysis

The value of specific consideration of risk, particularly for major weapon system acquisition programs, is becoming more apparent as specific risk-analysis techniques are developed and applied on a broader basis. For example, the specific cost data provided to the Defense Systems Acquisition Review Council by the OSD Cost Analysis Improvement Group compares alternative views of program costs (contractor, service, OSD). The OSD and the service-independent estimates are presented as point estimates of most-likely cost and include a range of uncertainty within which the ultimate cost will actually fall.[20] In addition, the General Accounting Office has recommended the use of a range of cost measuring risk and uncertainty in major programs as an aid to decision-making.[21]

In addition to the value in developing cost-probability distributions as an input to decision-making, risk analysis also provides substantial benefits to the program manager in his day-to-day management responsibilities. For example, risk analysis early in a program is one of the best ways to develop a careful, detailed program strategy and plan, and to better determine the cost, schedule, and performance constraints of a program at the earliest phases where the pay-off is greatest. By focusing attention on each program activity, the likelihood of adverse surprises is greatly reduced, and the program manager will be better able to optimize the allocation of resources to the various program activities. Finally, as the accuracy of management and design approaches increases through the use of probabilistic parameter descriptions, there should be a better chance of developing the optimum system to meet the military need.[22]

Conclusion

In spite of a great deal of study and many attempts at corrective action, DOD weapon system acquisition programs continue to be plagued with cost growth, schedule slippages, and performance deficiencies. The paradox is that most people working in this area in government and industry honestly desire that the situation be otherwise, and they share a continuing frustration that significantly improved results have not resulted in spite of increasing attention to the problem.[23] As presented in this paper, there appear to be a host of causes and categories of cost growth, many of which are not controllable by the person who often takes the heat when there is a problem—the program manager. One technique with significant potential for improved program management is risk analysis. The explicit consideration of risk can lead to better planning, management, control, and decision-making—the essence of program management.

20. Davis.
21. Comptroller General of the United States.
22. Lochry.
23. *Ibid.*

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